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ORIGINAL ARTICLES.

I.—Note on the Skeleton of *Diaphorapteryx Hawkinsi*, Forbes, a large extinct Rail from the Chatham Islands.

By C. W. Andrews, B.Sc., F.G.S., of the British Museum (Natural History).

(PLATE XII.)

IT is a well-known fact that many islands in which there is no indigenous mammalian fauna, have been, and in some cases are still, inhabited by flightless birds, which are usually of considerable size. Mauritius and Rodriguez are good examples of such islands; in the former the dodo and aphanapteryx, in the latter the solitaire and erythromachus, existed at least as late as the beginning of the seventeenth century, when, owing to their inability to escape from their foes by flight, they fell easy victims to the crews of ships touching at the islands, and also to the various domestic animals, such as dogs, cats, and pigs, introduced by man.

A notable addition to the ranks of such islands was made in 1892 by Dr. H. O. Forbes,[1] by his discovery of the remains of several forms of flightless birds on the Chatham Islands. This group lies in the South Pacific, about 500 miles east of New Zealand, in about latitude 44°; it consists of one large island (Wharekauri) and several smaller ones, the geological structure of which indicates that they form part of an old continental area, and are not oceanic islands.

The birds, as might be expected, belong for the most part to species found also in New Zealand, but such characteristic flightless forms as *Aptornis*, *Cnemiornis*, the Dinornithidæ, and *Apteryx* are wanting. Instead of these, however, we find *Diaphorapteryx Hawkinsi*, a large extinct coot (*Palæolimnas Chathamensis*), and *Cabalus Dieffenbachii*, all of which are now extinct, although the only known specimen of the last-named was killed as lately as 1840. Several species, such as *Palæocorax moriorum*, in which the wings had not undergone reduction, likewise occur in a fossil condition only. The bones are usually found either in the kitchen middens of the aboriginal Moriori or in the blown sands round the coast.

[1] Nature, vol. xlv, p. 580.

The most interesting of the extinct flightless birds discovered by Forbes is *Diaphorapteryx Hawkinsi*, a nearly complete skeleton of which is figured on Plate XII. This remarkable bird is a rail closely allied to *Ocydromus*, of which several species, all incapable of flight, inhabit New Zealand. It is also very similar to *Aphanapteryx Broecki*, of Mauritius—indeed, Forbes has referred it to the same genus, although for a time he placed it in a separate one, *Diaphorapteryx*. In a detailed account of the osteology of this bird by the present writer,[1] it was shown that it differed from *Aphanapteryx* in many points, particularly in the form of its metatarsus, and the name *Diaphorapteryx* was therefore adopted; in a recent memoir by Prof. A. Milne Edwards[2] on some of the Chatham Island birds the same conclusion is arrived at.

The skeleton here figured consists almost entirely of bones belonging to one individual, but the deficiencies have been made good from the immense collection of bird-remains lately obtained from the Chatham Islands by the Hon. Walter Rothschild, in whose museum at Tring the present specimen is preserved. The skull is chiefly remarkable on account of its relatively large size and long curved beak. In the vertebral column as mounted there are twenty-three free vertebræ, thirteen of which are cervicals, two cervico-dorsals (with short free ribs), and eight dorsals; the number of cervicals is no doubt correct, but it is possible that a dorsal too many may have been introduced. The pelvis, as in most flightless birds, is relatively large; it is very similar to that of *Ocydromus*. The pelvis figured by Milne Edwards in the memoir mentioned above (pl. xi, fig. 7; pl. xii, figs. 1 and 2) is certainly not that of *Diaphorapteryx*, or, indeed, of any rail, but seems rather to belong to some anserine bird. The hind limbs are long and powerful, well adapted for running, and also, judging from the stoutness of the metatarsus, for scratching in the earth. In *Aptornis*[3] the metatarsus is even more massive, so that in this respect, as in several others, *Diaphorapteryx* comes midway between that bird and the living Ocydromine rails. The sternum is very like that of *Ocydromus*, but the keel is still more reduced. The coracoids are very small, and appear to have made an obtuse angle with the scapulæ, as is usually the case in birds incapable of flight. The wings are very small in proportion to the bulk of the bird, the metacarpus especially being extremely short.

I am indebted to the Hon. Walter Rothschild for permission to figure this specimen, and also to my colleague, Mr. A. Gepp, for the photograph reproduced.

[1] "On the Extinct Birds of the Chatham Islands." Pt. I. The Osteology of *Diaphorapteryx Hawkinsi*.—Novitates Zoologicæ, vol. iii (1896), p. 73, pl. iii.

[2] "Sur les Ressemblances qui existent entre la Faune des Îles Mascareignes et celle de certaines Îles de l'Océan Pacifique Austral": Ann. Sci. Nat. (Zoologie), ser. viii, vol. ii, p. 117, pls. xi–xv.

[3] A skeleton of *Aptornis defossor* was figured about one-sixth natural size on Plate X of the present volume.

II.—The Origin of Nitrate in Chili.

By Dr. William Newton, F.I.C., F.C.S.

FROM the first discovery of nitrate in these provinces it has been an interesting question as to what caused it to come into existence here in such abundance, and, as far as our present knowledge goes, nowhere else in the world in such quantities.

Many theories have been formed attempting to explain the presence of these deposits of nitrate; the most popular, and a theory also accepted in scientific works, being, that in past ages the nitrate pampas were sea-beaches, and that an enormous quantity of seaweed was piled up on them. In course of time these beaches were elevated above sea-level and the seaweed decomposed, leaving its nitrogen in the state of nitrate and its small quantity of iodine as iodate.[1]

Darwin suggests that the plain of Tamarugal was either a lake or an arm of the sea. If it were an arm of the sea, he at once jumps his previous estimate of 400 feet elevation of the coast of Peru to 3,000 feet and over. The sea-shells which he notes are only found with caliche (the raw nitrate) in one or two places where the nitrate bed is in contact with the Chalk, and are evidently the remains of organisms from that formation. It is unfortunate that in the great naturalist's short visit to the nitrate districts, he was apparently not informed of the periodical floods which come down from the Cordilleras on an average about every seven or eight years, and flood the whole of the plain for a short time.

The present surface soil of the pampa is evidently due to the silt carried by these floods, and as far as borings have gone the underlayers of alluvial, and, indeed, the whole filling up of the valley, are due to the same periodical action.

Apparently the plain has never been the bed of a lake, at any rate in geological times commensurate with the soluble surface deposits, unless these occasional floods can be called lakes.

The origin of this sea and seaweed theory is chiefly due to the fact, that previous to the time of producing iodine from nitrate liquors, the only source of iodine was "kelp," the ash of burnt seaweed. The decomposition of seaweed, as also all organic matters under certain circumstances, does produce nitrate. The presence of large salares on the pampas, in proximity to the nitrate, also gives colour to the idea of the former presence of the sea.

But one must bear in mind that even the salt of the sea is derived originally from the washings of the land. There is no more reason to suppose the salares are evaporated sea-water than that any of the inland salt lakes of the world were originally connected with the sea. Inland salt lakes derive their salt from the washings of the soil surrounding them. The water running into the lakes may not be very salt, but if there be no outlet from the lake, the constant evaporation, especially in hot climates, gradually concentrates the salt in them, sometimes all the water being evaporated and only a salar left.

[1] Darwin's "Naturalist's Voyage"; Watts' "Dictionary of Chemistry, etc."

Salares are also formed by the water below the surface of the soil being drawn up by capillary attraction and constantly evaporated, giving place to fresh supplies and evaporation.

To the seaweed theory of the formation of nitrate there are at least three insurmountable objections. The first is that seaweed contains bromine as well as iodine. Most of the caliche in this province does not contain bromine, as it would have done if it were derived from seaweed. There is no process in nature which could completely separate bromides from a mixture of iodates, chlorides, and nitrates. Secondly, there are seldom sea-shells or other sea débris in or near the nitrate deposits. There would necessarily be these if it had been a sea deposit. Thirdly, the stones in the caliche and its neighbourhood are sharp and jagged, showing no signs of being water-worn, as they would do if they had existed on a sea-beach.

There is another suggestion which finds much favour—that is, that nitrate may have been derived from the decomposition of ancient guano deposits. As evidence towards this, is put forward the presence of birds and their remains in the caliche. These birds have, however, apparently been always insignificant in numbers. The same birds exist at the present day, building their nests in crevices in the ground, and they have sometimes been blown up alive in the calicheras. Their guano, although in a few spots on the pampa rather prominent, is in reality little more than a colour, and the amount of nitrate which could be produced from it must be more insignificant than that of the village sewage. The great disproof of the guano theory, however, is that we find no accumulation of phosphate which would necessarily occur in a corresponding amount to the nitrate, if this idea were true.

There are other theories also put forward to explain the caliche deposits, which are scarcely worth discussing, among them being one attributing the presence of nitrate vaguely to some volcanic action. The well-known principle in scientific investigations, "Never to invent exceptional theories as long as the ordinary workings of nature are sufficient to explain the facts," should be applied in this case.

Nitrate exists in small quantities all over the world, in every fertile soil. Vegetation cannot grow without it. How, then, does it originate in these ordinary soils? It originates from the oxidation of the organic materials and ammonia in the soil. This oxidation is brought about by the action of microscopic organisms, called "nitrifying germs."

Prof. Warington by his experiments has shown that the most favourable conditions, for the active life and work of these nitrifying organisms, is a porous soil containing plenty of vegetable or animal organic matter, together with sulphate of lime and an alkaline base such as carbonates of potash, soda, or lime. Given a soil of this character, the amount of nitrate produced by the action of these organisms will vary with the temperature; the rate of manufacture of nitrate being more rapid in a high summer temperature, and diminishing as the weather gets colder.

In ordinary agricultural soils, unless they are lying fallow, this nitrate is greedily absorbed by the plant almost as fast as it is produced. In fact, except in the case of leguminous crops (clover, beans, peas, etc.), it is almost certain that the plant can only absorb the nitrogeneous food necessary for its growth when it is in the form of nitrate.

Now, in the enormous plain of Tamarugal we have a porous alluvial soil containing organic matter, chiefly of ancient vegetable origin. The soil contains also sulphate of lime and is basic in its nature, the water percolating through it containing carbonate of soda. The temperature is high, and, in fact, we have all the conditions which Prof. Warington has pointed out as favourable to the rapid conversion of the nitrogen of organic matter into nitrate. On account of the absence of rain in this district, there is now no growing vegetation to absorb the nitrate, and therefore it must accumulate.

Now let us look at the conformation and situation of the plain of Tamarugal. On one side we have the high Cordilleras running north and south; then we have this alluvial plain about 30 to 40 miles wide with a very gradual downward slope to the west, where it is again shut in by the coast-line of hills running practically parallel to the Cordilleras. The waters of the western side of the Cordilleras have no escape, except by passing through the soil of the plain. At the western side of the plain the waters are stopped by the coast-line of hills, forming a complete wall from north to south. At the foot of the eastern or landward side of this wall of hills, some thirty miles from the sea, and at the lowest about 2,500 feet above sea-level, these drainage waters of the plain gather and evaporate, giving up all the salts they have dissolved in their long passage through the soil. The mountain floods which swamp the plain of Tamarugal, at intervals of seven or eight years, are chiefly responsible for the transportation of nitrate from the superficial layers of the pampa soil. It is along the line at the foot of these hills that all the nitrate grounds are situated. Their situation, always on the landward side, is an indication that the caliche is derived from the land, and in itself almost an absolute disproof of the guano or seaweed theories. The occurrence of the nitrate so often up the first slopes of the hills seems at first view strange. But we can see by a simple experiment how this could have happened. If we put some nitrate or salt dissolved in water in a saucer, and allow it to evaporate, we shall see that immediately it has evaporated, so far as to become a saturated solution, the deposit of crystals of nitrate or salt begins to creep up the sides of the saucer and even over and down the other side—just as the caliche has crept up the lower slopes of the hills through the porous earthy strata known in Chili as cova and congelo.

This origin of nitrate is important, amongst other reasons, because one of the great drawbacks to the sale of this material is that many farmers look on it with prejudice, calling it an artificial or chemical manure. It ought to increase its sale, when it is proved to them that, instead of being an artificial manure, it is in reality

the concentrated fertility of the thousands of square miles of land between the watershed of the Cordilleras and the coast-line of hills.

The plain of Tamarugal is a huge, practically inexhaustible reservoir of nitrate. And this nitrate has been gradually washed down to its western or lower side. The alluvial of this belt of country is on an enormous scale; the same thing as the heaps of mud, organic refuse, and lime which the French farmers were by law compelled to make in the time of Napoleon I, in order that these heaps should ferment, and on washing yield nitrate for gunpowder.

There are some very important questions for Chile and the nitrate officinas which arise from the above facts. Among them are: How far does the present supply of water tend to deposit nitrate again in the same grounds? Can this action be assisted and accelerated by artificial means?—such as uncovering the ground down to suitably porous strata and allowing the sun to have its full evaporative action, collecting the nitrate as in the saltpetre soils of India and Burmah.

III.—On the Existence of Rich Phosphate of Lime in the London Basin.

By M. N. de Mercey, Collaborateur au Service de la Carte Géologique de France.

THE proof which I gave in June, 1891,[1] of the production of "rich phosphate" by enrichment of phosphatic chalk through the influence of the Tertiary deposit called "bief," enabled us to foresee the existence of similar rich phosphate in the London Basin; since phosphatic chalk, analogous to that which I had described or discovered in Picardy, especially at Hardivilliers and Hallencourt, had been discovered by Mr. Strahan and described by him in an interesting paper "On a Phosphatic Chalk with *Belemnitella quadrata*."[2]

I have recently examined the Taplow chalk, and am indebted for facilities for doing this to Mr. Grenfell, on whose property it occurs. This examination enables me to record the existence of "rich phosphate" occurring under precisely the same conditions as in the French localities.

At Taplow, as in Picardy, the rich phosphate must be regarded as a product concentrated from the phosphatic chalk under the influence of the deposit at the base of the Tertiaries. The rich phosphate occurs as a sand of pale chamois colour, in a pocket similar to the pockets in the Chalk of Picardy.

The pocket at Taplow with the rich phosphate occurs at about two metres from the surface of the soil, and under a Tertiary deposit. The central part of the pocket is, as usual, filled with reddish sand, quartzose and argillaceous, and more or less agglutinated, the siliceous element being in grains or fragments, worn and rounded. The rich phosphate occupies the bottom of the pocket to a thickness of 1 metre 50 centimetres, and with a diameter of about 1 metre. An analysis of the phosphate gave 30 per cent.

[1] Bull. Soc. Géol. France, 3e sér., t. xix, p. 867 *et seq.*
[2] Quart. Journ. Geol. Soc., vol. xlvii, p. 356.

of phosphoric acid, corresponding to 65·40 per cent. of phosphate of lime. The proportion of iron and alumina is only 1·51 per cent. Here, then, we have in the London Basin the same kind of rich phosphate which is worked in Picardy.[1]

IV.—Clays, Shales, and Slates.

By W. Maynard Hutchings, F.G.S.

(*Concluded from the July Number*, p. 317.)

I HAVE recently been examining a series of specimens of Silurian slates from Scotland, specially collected because of the very intense shearing they have undergone. These and the accompanying other rocks are all crushed and torn out in a most remarkable degree, and the microscope shows how severely their constituents have been acted upon mechanically. Yet the crystalline and mineralogical development is seen to be but very moderate indeed. The micaceous mineral is all in one plane, and transverse sections, in polarized light, show that it is a felted, wavy, and puckered mass of interwoven flakelets, with chloritic substance intimately diffused among it, and still more apparent in separate little streaks and lenticles. The small amount of quartz present is rolled out into long, thin lenticles also. But the micaceous mineral itself is not at all far advanced, either as to size of its flakes or the nature of the mineral. It is still an impure, rather deeply-coloured greenish-yellow substance; not any of it has arrived at the stage of muscovite, and dehydration shows, in a remarkable manner, how very considerable its impurity still is. In its original condition, the slate gives sections which present a very uniform appearance under the microscope. The colour is the same all over, and the only indication of the presence of bands of varying nature is found in a very slight increase, in some layers, of the coarseness of grain and of the number of quartz-lenticles, and in the diffusion of the chloritic substance. But after heating the specimen, the effects seen in the sections are most striking. There are now many bands of different colours, yellow, red, greenish-brown, and brown, presenting very strong contrasts, and showing that noticeable differences in chemical composition must have existed in different thin layers of the seemingly homogeneous slate. Not only the interwoven chlorite, but also the micaceous mineral, has taken on these tints in very decided degrees. It must have been unusually impure. It has lost, after heating, nearly all its action in polarized light.

The lenticles and the small grains of quartz have also become much more apparent than before heating, and, indeed, this case serves as a good example of how useful this method can be made in assisting us to obtain a knowledge of the nature of rocks of this class.

[1] A specimen of the "rich phosphate" of Taplow was exhibited at the Geologists' Association at the meeting on July 3, 1896, and is now placed in the Museum of Practical Geology.

Analysis shows a specimen of this slate to contain 4·96 per cent. of total alkali, a total amount of iron equal to 7·64 per cent. of ferric oxide, and 6·24 per cent. of magnesia. This last is an unusually high figure for a slate of this class. It would correspond to a large amount of chloritic mineral, and the heating shows that a good deal more of such mineral is present than is made evident in ordinary sections; but still there is not enough to account for so much magnesia, and no doubt much of the latter is combined in the micaceous mineral.

Although these slates have resulted from very fine-grained deposits, there are still some small flakes of clastic muscovite unmistakably recognizable in the ordinary sections, and still more so in the dehydrated ones; and these seem strikingly to emphasize, by contrast, the above points as to the nature of the main mass of the new micaceous mineral of the rocks. The mere fact that these few small clastic flakes are still so distinct from the main mass, shows how little progress in development has been made, compared with what we see in more regenerated slates, in which great quantities of new muscovite have been formed, and in which original clastic flakes have either been absorbed into the newly-formed materials or are quite unrecognizable among them. In fact, if we compare these ancient and intensely sheared slates with some of the sections of shales previously alluded to, we see that the mica in them is practically the same as that in the more crystalline and felted bands which we have observed in the shales.

The same applies to strongly-sheared Cambrian slates from Saxony, and to many other examples studied.

All this emphasizes the fact, frequently pointed out, that intense dynamic action, even allowing for its influence being added to and associated with that of depth-conditions, does not necessarily bring about any commensurate effects, other than purely mechanical ones, in rocks similar in chemical and mineralogical composition, and in nature of origin, to others which we see very highly developed.

If, now, we turn to the question of the development of rocks in "contact-areas," it will be advisable, for our present purposes, to fix our attention, not so much upon the more intensely altered examples, with a large formation of special contact-minerals, as upon those which are less affected in this way, in which we can observe the increase in the regeneration of the already existing micaceous constituent, with the further separation and rearrangement of the chloritic substance.

In a considerable proportion of cases we have a formation of brown mica in quite early stages of the metamorphism, and this partly complicates the subjects to which we are at present paying attention, as the chloritic substance may be largely, or even wholly, used up in the production of this brown mica. This formation of brown mica also considerably obscures the white mica, and, indeed, there seem to be cases in which the impure complex mineral of the slates is altered, at once and directly, into a pale-brown mica which is something intermediate between muscovite and biotite.

But we can find examples enough of contact-slates in which brown mica and chloritic mineral are developed together, and accompanying a recrystallization of the micaceous mineral to muscovite; or we may have rocks in which a very high degree of recrystallization has been reached without any brown mica being formed at all. In such rocks we see, among the main mass of the slate-mica, the crystallization of undoubted muscovite, at all angles to the plane in which the slate-mica lies flat; and we may see this in all degrees up to the point at which we get a completely regenerated rock, consisting mainly of a criss-cross mass of muscovite-flakes and crystals.[1]

The newly-formed chloritic mineral is often seen to take a degree of crystalline development and of individualization proportionate to that taken by the mica; where this latter mineral forms sharply-bounded plates, they are not infrequently grown together with equally sharply-defined individuals of chlorite, sometimes one of each, sometimes one sandwiched between two of the other, and clearly crystallized under the same conditions and at the same time. We also see the chloritic matter sometimes take the form of larger indefinite bodies, in which crystals of muscovite lie in all directions, their cross-sections giving a structure exactly comparable to the "ophitic" of igneous rocks; or again, we see it jammed in the angles among intercrossing mica crystals, in just the manner which is called "intersertal" in the case of the ground-mass of basalts, etc.; all these structures distinctly showing the simultaneous origin of the two minerals.

In studying these recrystallizations due to contact-action, we come again upon the question of the "spots" which are so frequently found largely produced in just those less highly altered portions of contact-areas which we are now considering. About two and a half years ago I made some remarks and suggestions on these little-understood spots (Geological Magazine, Jan. and Feb. 1894). Since then I have paid a good deal of attention to the subject, and examined a large amount of material, the result being, I hope, to throw a little more light on their nature and mode of origin, and to connect a large part of them with the processes of rock-development which I have endeavoured to outline above. In the paper in question I wished to show what good reasons we have for a conviction that the striking recrystallizations we see in contact-rocks are brought about by the means of some sort of mineral solution which is formed in the sedimentary rock; the components of the original materials of the rock being more or less taken up into this solution, and again crystallized out of it in new forms of the same or other minerals.[2]

[1] By *crystals* are here meant those individuals of muscovite which stand out in distinct and definite plates, with perfectly parallel edges, sharply marked off from any more confused mass of irregular flakes.

[2] For the consideration of the question here involved, it is quite immaterial whether this solution is formed entirely by the action of heat and contained water on some of the components of the sedimentary rock, or whether it has received additions in the form of alkaline liquids from the intruded igneous mass.

I suggested, tentatively, that some of the "spots" were possibly due to portions of this solution, which, in the outer portions of the contact-aureoles, "would tend to draw together as little spots and patches," and so consolidate among the other ingredients of the rock. I still think that this, to a considerable extent, expresses the state of the case; but that it needs a little amplification. These spots, although in the outer contact-areas, do not occur except where a decided amount of recrystallization is already taking place. This recrystallization, as we have seen, consists largely in a development towards muscovite, with a rejection of the chloritic constituents of the original micaceous mineral. These constituents pass over into the solution which permeates the rock, and are themselves, in these cases, deposited out of this solution, and with residual portions of it, in the manner suggested to form the "spots."

I formerly described in detail the nature and appearance of many of these "true spots" in several occurrences. They are, in fact, due simply to another form of the concurrent separation from the slate-mica of purer mica and of chloritic bodies. Like the interwoven chloritic matter, they vary in all degrees of green and yellow tints, and some, again, are almost colourless in thin sections. They vary also in degree of optic activity in a similar manner; we get spots of true chlorite, and we get all gradations from this of apparently quite indefinite compounds.

The frequent aggregation in the spots of iron-ores, of ilmenite-flakes, of rutile, anatase, etc., is to a large extent part of the same process of separation and recrystallization of formerly combined materials.

In my former notes I urged that it was desirable to make a strict separation between "true spots" and certain indefinite grains, or imperfect crystals, of particular minerals. But this opinion I would now modify and partly withdraw, after more extended observation. One sees so many cordierite grains which exactly resemble spots in mode of occurrence; and here and there one sees such clearly apparent cases of gradual transition from chloritic spots into definite cordierite, that a strict separation is not practicable. The passage from a chloritic substance to cordierite does not require any *qualitative* change. It only needs the removal of water, and a certain degree of molecular interchange with a permeating solution; and thus we so often see the occurrence together of chloritic and cordieritic spots, or the giving way of the former to the latter as the contact-action increases in intensity.

Similar considerations apply to staurolite, but the transition is not, in any case that I know of, so apparent; nor does this mineral occur nearly so frequently as cordierite.

Again, spots of chloritic nature pass over in a similar manner into biotite, and here also no line can be drawn;—the biotite is often as truly a spot as is the chloritic substance.

We may thus satisfy ourselves, by examination of a sufficient number of contact-slates, that here, again, the main change in them, in their earlier stages, before we come to the more intense actions

of the inner zones, is based upon this same tendency of the micaceous mineral to take higher development and to reject some constituents; and that to these rejected constituents is due the formation of chlorite and allied bodies (often taking the form of "spots"), of biotite, of cordierite, and of staurolite. And we may note that even in very moderate degrees of contact-action, we can get effects which are not in any way approached by those of some very intense manifestations of dynamic action.

As regards the third agency for the crystalline development of slates, it is not possible to say much, because *direct* evidence of any value is practically absent, excepting what is rather on the negative side. That is to say, we have plenty of cases in which we know that rocks have been at one time under enormous thicknesses of cover, so that if simple depth-conditions could bring about the sort of crystalline development we are considering, we might look for its very marked appearance; yet we do not see any striking degree of it, but only such very moderate stages as we have already noted in some of the sheared slates.

On the other hand, we have rocks in which such development is carried to a very high point, in a manner closely paralleled in contact-areas, but without any proof at all of contact-action, and with strong evidence in the rocks themselves that this development was not accompanied by crushing and shearing. We cannot here deny the possibility that what we see is the result of simple depth-conditions; but it is quite open to us to say that a much more probable cause is the action of concealed igneous masses; and, indeed, this view seems rather the more rational, having regard to the strong evidence for the very moderate effects of depth-conditions, either alone or together with dynamic action.

We can only leave this question an open one, awaiting further evidence; and simply note the fact, that where we have these cases of high development, not directly accounted for, they are always on the same lines exactly as in contact-areas, and are often plainly not dynamic.

The main point important to emphasize in all such observations appears to be that both in contact-development, and in this development which we cannot definitely ascribe to contact-action, we always get more or less of a decided advance to muscovite; whereas, in so many cases of intense dynamic action, we see that the micaceous mineral is not nearly so far advanced. There has been some progress, but it does not seem to be able to go beyond very moderate limits, and it leaves the slate with an impure mass of felted mica, of complex nature, among which no well-marked separate flakes and crystals have begun to develop themselves. Moreover, even this very moderate degree of progress we cannot safely place to the credit of dynamic action, as depth-conditions may have caused it. And, indeed, in other cases not dynamically affected, we may see that just such a moderate crystalline development has taken place on much the same lines.

It may be, and it does not seem at all improbable, that a

sufficiently extended investigation of slates, over many and large areas, would show us that there is a form of mineralogical and *structural* development which, even in its very beginnings and early stages, could be sharply distinguished from anything which could be produced either by dynamic action, or by depth-conditions, or by a combination of these causes, operating on the same original materials. If such a distinctive development could be recognized and established, it would obviously be of very great value in geological work. But, equally obviously, another great difficulty comes in, which I can best illustrate by an example.

I have before me a rock which represents an extremely and unusually high development of the kind to which I allude. All the mica is muscovite in fine large crystals, lying in all directions. Not a trace of impure original mica is left. Chlorite is largely developed, and is to a considerable extent as well crystallized as the mica.

There are the usual accessory constituents of highly-altered sedimentary slates. There is no parallel structure now remaining; the rock may have been sheared to any extent *before* this crystalline development took place, but shearing did not accompany the development, and it has not suffered at all from such action *since*.

But if it *had* suffered shearing in a sufficient degree, at a later period, all trace of the present *structure* would be destroyed; the rock would be a perfect muscovite-chlorite schist, with these minerals rolled out and arranged more or less parallel.

It might then be claimed as a dynamically-produced rock; and though this would be quite true of its structure, it would be quite untrue of its mineralogical development, with which the shearing would have had nothing whatever to do. This is probably the history of a great number of schists and allied rocks, which have been derived from ordinary slates by other causes and afterwards sheared. It is this obvious danger of a double causation being wrongly ascribed to one source only, which makes it so important to investigate carefully, whenever possible, all cases of separate action, so far as any really separate action has ever taken place.

In studying the alterations in mineralogical and structural condition caused by igneous intrusions, it is not at all necessary to limit our observations to the larger manifestations of contact-action around masses of granite or allied rocks. On the contrary, basic intrusions of less magnitude will often serve even better to bring to notice some of the particular points we have been considering; and of all the rocks I have examined in this connection, none have been more instructive, or clearer in their indications, than a large series of Lower Carboniferous shales altered by the intrusion of the Whin Sill.[1]

In these we can see what effects have been produced on such simple shales as I have described in this and former papers. We

[1] These rocks form part of a large number collected by Mr. E. J. Garwood during a long period of detailed work on the geology of the Whin Sill in Durham and Northumberland.

have these quite early and undeveloped stages of the materials of which slates are made, and we see them altered direct into contact-rocks, with development of muscovite, and with a totally new *structure*. And as they have been left for us in a condition practically not affected by any dynamic action since their alteration, they present us with a particularly good material for study.

We find that soft shales have become hard compact rocks, and microscopic examination of many of these shows that they consist more or less largely of a criss-cross network of flakes and crystals of regenerated mica, with no relationship whatever to the original plane of the micaceous mineral of the shales. The degree of this regeneration is, of course, variable; but in the most advanced cases it is very complete.

The development of chloritic material concurrently with the mica is again well seen. In many cases the mica is largely formed into tufts and radiating sheaves and bundles; and in these we frequently see that it and the chlorite have crystallized together into such aggregates.

It is very rare to find biotite formed in these Whin Sill rocks, so that when we are examining the more advanced phases of alteration of very quartz-free shales, we usually have a product made up almost wholly of mica and chloritic material.

"Spots" are exceedingly abundant in many of these rocks; and though much smaller than at most granite-contacts, they are exactly analogous in all other respects, and vary similarly in colour, etc. Indeed, their nature and mode of origin are more easily made out here than in most contact-areas. Just as we have rocks at granite-contacts which have not formed any spots, so we have them here, the chloritic element being diffused among the mica in all stages, from quite indefinite and almost isotropic matter to more highly-developed chlorite; while in other cases we have these same varieties of chloritic matter collected into crowds of spots. It is curious to observe how, sometimes, the organic pigment of the shales is concentrated in the spots, leaving the micaceous areas clear of it; whilst at other times the converse is the case, the spots being free and the pigment remaining in among the muscovite.

As an instance of these spotted rocks I may mention one from Rowntree Beck, which occurs 18 feet below the Whin Sill. It is mineralogically quite regenerated, no remnant of original mineral being seen; but it still contains fossils. It was a shale practically free from visible quartz, and is now altered into a mass of white mica and chloritic matter, of which latter a very large part is in the form of almost spherical spots, averaging $\frac{1}{20}$ of an inch in diameter, of dirty yellow-brown colour, into which most of the organic pigment has concentrated. These very abundant spots lie in a field mainly of pure white mica, large portions of this field being relatively clear and colourless in ordinary light, and showing with crossed nicols well-developed flakes and crystals in all directions, and a good many sheaves and spherulitic aggregates. Among this mass is disseminated a good deal of yellow-green

chloritic matter, and the sheaves and radiating groups are partially composed of it.

Apart from mere size of constituents, it would not be possible to find more characteristic recrystallization than we see in this and some other of these shales, the whole mode of development being the same as at granite-contacts.

In connection with the subject of certain developments in sedimentary rocks, apart from any demonstrable contact-action, and with which developments dynamical and regional causes are credited, I would like again to allude to some of the occurrences in the Ardennes. In a former paper (Geol. Mag., March and April, 1895), I pointed out the occurrence of abundant "spots" in the coticule of Viel Salm, and in the dark slate with which it is associated. I particularly described these spots from their special points of interest, as they are perfectly colourless and absolutely indistinguishable in ordinary light, and are uniformly dark and isotropic between crossed nicols.

The thin bed of pale-yellow coticule does not differ from the accompanying dark rock in the nature or degree of its development. But it does differ very much in the fact that it is free from iron ores or other dark matter, so that sections of it enable us to study, without impediment, its mineralogical and structural condition. We see that its mica is all quite clear muscovite, and that nothing is left of any original impure micaceous mineral. No chloritic matter can be made out in sections from the specimens I have examined; what there is of it is quite colourless and invisible in thin slices. The rock is unusually free from iron. Renard gives in its analysis only 1·05 per cent. of ferric oxide and 0·71 per cent. of ferrous oxide, with 1·13 per cent. of magnesia. He calculates from these data that the rock contains 8·74 per cent. of "chlorite"; but, of course, this is only an approximation, as the calculation supposes a definite composition of the chloritic mineral, which there is not any reason for thinking that it possesses.

A thin transverse section cut from a specimen of coticule after dehydration, brings to view the chloritic mineral as a light greyish-brown substance now quite conspicuous among the mica at some parts of the slide; it is not evenly diffused all over it. The muscovite is not in any way altered by the heating.

A very interesting point brought about by examining the dehydrated rock, is that the spots in it are not in any way affected, but remain just as indistinguishable in ordinary light as before. Whatever is their real nature, it is clear that they do not consist of a hydrated chloritic material. And, indeed, it must be borne in mind that, though spots of the chloritic nature we have been considering are so frequent as to make out a very large proportion of these interesting bodies, there are also other varieties of them which do not come under this description, and which are due to the formation of other combinations during the recrystallization of the rock-constituents.

V.—Change of Form by Expansion as an Element in Mountain-Building.

By T. Mellard Reade, C.E., F.G.S., etc.

SOME critics of my theory of the "Origin of Mountain Ranges" appear to have strangely lost sight of one of the essential principles upon which it rests. This seems to have arisen through their attention having been too much engrossed with what I have said on the subject of cubical or volûminal expansion.

In my original work it was shown that the calculations of the earlier investigators on the vertical lifting of a given thickness and area of the earth's crust, by a given rise of temperature, must be multiplied by three to arrive at a correct result, as they omitted to consider the expansion in two horizontal directions at right angles to each other, confining their attention to linear expansion in a vertical direction. But, while calling attention to this oversight, it was certainly not my contention that expansion would affect the earth's crust like the expansion of water in an inexpansible vessel.

The effect of expansion on a solid body like the earth's crust by differential heating is to set up stresses and strains which relieve themselves in the direction of least resistance, and in doing this an internal movement and change of form ensue. A change of volume of a section of the earth's crust therefore involves internal movement, distortion, and change of form.

This principle I illustrated by experiments on the ridging up produced by heating sheets of lead; by the distortion of a sheet of zinc and iron, rivetted together, and placed in an ordinary oven; by the well-known wrinkles and folds that occur in lead gutters, lead-lined baths and sinks; and since, by the permanent expansion which frequently takes place in terra-cotta copings of walls through differential heating by the sun's rays.[1] I could add considerably to this list, but it is sufficient for my present purpose. The ridgings up and distortions were shown in all these cases to be the cumulative result of compressions and tensions set up by successive expansions and contractions, due to alternations of temperature, ending in a permanent extension in the case of a sheet, which is compensated for by folds or wrinkles, or in the case of a bar by lengthening.

Applying this principle to the probable effect of changes of temperature in the earth's crust, I showed that the strata of which mountain chains are composed have a wide areal extension, as in the plains of Russia, which are composed of the Silurian and other rocks involved in the Ural uplift. The same principle was shown to hold true with the Appalachians; and later, in this Magazine, I have called attention to British geology as teaching us a similar truth.[2] These strata out of which mountain ranges are evolved may be considered as wide and extended sheets almost paralleled on a small scale, excepting for the variable thickness distinguishing geologic deposits, by the sheets I experimented upon.

[1] Geol. Mag., Dec. III, Vol. V, pp. 26, 27.
[2] Geol. Mag., Dec. IV, Vol. II, pp. 557–565.

Without, however, considering the *causes* of changes of temperature in the earth's crust, which I have treated of in other communications, it is sufficient for our present purpose to accept the fact that profound changes do occur. Beginning with Hutton and Playfair, I can think of no geologist who has written upon the subject of metamorphism and geological dynamics who fails to call to his aid, in some form or other, the effect of heating upon the sediments which compose the rocky covering of our globe.

If it be assumed, then, that a great sheet built up of various strata of sedimentary origin, with, perhaps, intercalations of ashy and igneous beds, combinedly reaching in places thicknesses measured by miles, is by slow degrees subjected to a fluctuating rise of temperature, it is evident from the illustrative experiments referred to that not only a linear vertical expansion will ensue, but that the horizontal expansion, as much greater in proportion as the areal extent is greater than the thickness, will produce, by small increments and minor alternations, a creep, ending in an anticlinal fold in a position determined by several conditions.

It is thus seen that an actual movement or displacement of material proportionate to the amount of expansion has taken place.

The excess of the material of this compound sheet, or what may be called the strata-plate, over the space it originally occupied, is compensated for by a heaping up by folding along a line of maximum pressure or least rigidity. In this way a permanent feature in the form of a fold has been built up upon the earth's crust, which may be increased in amplitude by future expansions, but which will remain unaffected by any succeeding contractions of the strata-plate.

Let us now consider how a contraction of the strata-plate can be compensated for. I have shown in my original work that it may be met, in the case of small contractions, by what I have called compressive extension, which is a lengthening of the strata by the compression of the overlying strata going on *pari passu* with the contraction due to a fall of temperature, so that, instead of separating by fissuring, the strata are made to continually occupy the same superficial horizontal space while, at the same time, becoming thinner by compression. As the greatest expansion takes place at the base of the deposits, or in the underlying crust, there is, in most cases, a load sufficient to act upon and mould the contracting bed, and in this way convert horizontal into vertical contraction, the rigidity of the strata and power of conveying lateral thrust being at the same time preserved. Therefore, in the case of a general rise of temperature of the strata-plate, but with minor fluctuations and falls of temperature, the effect of every rise, however small, will—whether the compensation be by compressive extension or by minor faulting and keying up—tend to still further lengthen the strata and develop the anticlinal fold, or to add to it other parallel anticlinals until a complete folded range is finally formed; or, as in the more extreme cases, such as the Alps, a central core or a series of ellipsoidal domes of gneissic rocks is forced up from below, throwing back the folds in fan-like form, and further compressing them. Certain secondary

effects may follow, such as the folding and formation of foot-hills by the gliding of the upper beds down the sloping flanks of the older beds; but it is unnecessary for me to dwell upon them here, as my object is to enable those to grasp who have not yet done so, the idea of successive cumulative expansions, as I conceive them to have acted in the building up of mountain chains.

But these expansions, caused by a general but fluctuating rise of temperature, diminish, and finally cease, by the dying out of the cause producing them. In the absence of compression no more folds are initiated, nor is the amplitude of the old folds increased. Meantime, the ever active elements in the form of air and water are busy at work, reducing and carving out of these folds domes and ridges, the mountain forms and scenery we are familiar with. Thus the cycle of change is completed, and the broken-up rocks are returned as detritus to the sea.

A general but fluctuating fall of temperature now sets in, and the rocks composing what I have called the strata-plate contract. This contraction can only be met in one of two ways—either by stretching or fissuring. In their nature rocks are incapable of stretching by tension, excepting it be in a very minor degree, and compressive extension could only partially compensate for the profound changes of volume which take place. No doubt the strata-plate will be eaten into, and underlain to a considerable extent, by semi-molten matter in a plastic condition; and the shrinkage of this, combined with the irregular shrinkage of the non-homogeneous material of the sedimentary strata, must inevitably initiate fractures. These fractures, we know, take the form of two series of normal faults, each series of which has a more or less definite direction and parallelism, and are classified as strike or dip faults, accordingly as they roughly follow the strike or dip of the strata. The voluminal contraction of the strata-plate is met by the sinking of wedge-like blocks of strata along and between these lines, or, rather, shear planes called faults, and the earth's crust thus remains solid by keying up. In adapting themselves to the voids these blocks are continuously or intermittently sinking, and certain secondary folding along a large fault often occurs. This is fully explained by the fact that the strata nearest to the earth's surface shrink least, so that the wedge, in adapting itself to the void below by sinking, is often in compression in the upper layers, which is met by the turning up of the edges of the strata against the fault-plane.

That this succession of events takes place in Nature, can be readily settled by appeal to any typical section of a mountain range, or to any of the numerous sections taken through the folded regions of Britain published by the Geological Survey.

This latter, it is almost needless to say, constitutes evidence of the best kind, as the authors were simply recording facts, having no thought in their minds of the theoretical relations here expounded. The posteriority of normal faulting to folding has been remarked upon by even so early an observer as Playfair.[1] Every section I have seen

[1] "Illustrations of the Huttonian Theory," pp. 62, 63.

shows normal faults cutting and displacing the folds where the faults and folds exist together, even in the case of those longer undulations into which the strata involved in the folding of the mountain range graduate in those great areas and plains flanking the range proper, which constitute a large proportion of what I have termed the strata-plate. May we not justly infer from these phenomena that normal faulting on a large or general scale never *precedes*, but invariably *follows*, folding, excepting in the case of previously faulted and folded strata involved in the general compression and uplift. Another feature distinguishing folded regions, such as Scotland, is the prevalence of enormous strike-faults, showing that normal faulting and folding, though arising from movements in opposite directions, are yet closely related.

This short restatement of some of the leading principles of my theory of the origin of mountain ranges seems necessary in view of certain misconceptions which have arisen, doubtless due to the complexity of the subject.

VI.—Note on a Section at the North Cliff, Southwold.

By Horace B. Woodward, F.R.S., F.G.S.

THE damage done to the land at the north end of Southwold by the "moderate gale" of May, 1895, has been described by Mr. J. Spiller.[1] One result of this damage was the opening up of an interesting geological section along the base of the low cliffs, a short account of which I brought before the last meeting of the British Association at Ipswich.

Before publishing this account, it was hoped some evidence might have been obtained of the age of a fresh-water bed that had been exposed. In this I have been disappointed, but as the sea continues its ravages all traces of the bed may ere long be removed, and it seems desirable, therefore, to delay no longer in making known the particulars of the section.

From the neighbourhood of two old pits that occur on the margin of the present cliffs to the north of the coastguard station, the lower portion of the cliffs has been bared of the talus so far as they extend northwards, and certain deposits have been revealed which were not previously to be seen, while other strata are more clearly exposed. Particulars of these are shown in the accompanying section.

By the present bathing-station, now just beyond the north end of the cliffs, there is a low bank of Boulder-clay that extends some ten yards north of the gravelly cove recently eroded by the sea. This cove shows a fine section of the Crag series, 15 to 18 feet deep in places, and extending for fifty yards. The beds comprise ochreous sand and pebbly gravel, somewhat irregularly accumulated, but on the whole fairly well bedded, and here and there current-bedded on a small scale. The stones are mainly flint pebbles, but many subangular fragments are present with the smaller stones, together

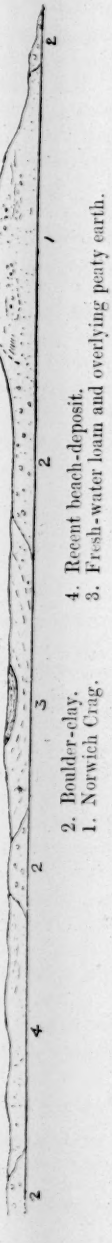
[1] Geol. Mag., Jan. 1896, p. 23. See also Howorth, Quart. Journ. Geol. Soc., vol. li, p. 496.

with quartz, etc. At the south end of this exposure there is an included small mass of shelly Crag. The shells are interspersed amid flint pebbles, and their preservation may perhaps be due to a thin overlying seam of clay.

Adjoining the Crag series on the south, the Boulder-clay is again seen, and here it has cut deeply into the Crag sands and gravels. The thin seam of clay (beforementioned), which has protected the shelly Crag, has apparently been pressed down, so as to truncate the edges of the Crag layers; and it thus follows the course of the overlying Boulder-clay. This Boulder-clay extends for about thirty yards to the south, where it is overlain by a thick bed of loam and laminated peaty earth—a fresh-water deposit that extends forty yards along the base of the cliffs, and much more towards their upper part, as the strata are bent into a gentle syncline, supported further south (as on the north) by Boulder-clay.

The Boulder-clay to the south of this fresh-water deposit extends for fifteen yards, and is then overlain by recent accumulations for a space of forty yards, and then again the Boulder-clay is shown.

It was in these last-mentioned recent deposits that a human skeleton was discovered in 1895, and the strata were at first supposed to belong to the Boulder-clay. The material is in part an irregular, brown, stony loam, with scattered pebbles and subangular pieces of flint, etc., and with also a number of chalk stones; in part it becomes bedded, much more sandy, and contains many more pebbles. The entire deposit, shown to a depth of six or eight feet, is a recent one, being a beach accumulation made up largely of reconstructed Boulder-clay, the materials being commingled with sand and shingle from the beach, or from the old and half-eroded gravel-pit against which the deposit occurs. It is clearly to be distinguished from the bluish-grey Boulder-clay; and that it is not weathered Boulder-clay, is shown by the roughly-bedded and in part false-bedded character of the newer accumulation, and by its containing a much larger proportion of



Section along the base of the north cliff, Southwold. (The upper part of the cliff south of the gravelly cove was obscured.)

2. Boulder-clay.
1. Norwich Crag.
4. Recent beach-deposit.
3. Fresh-water loam and overlying peaty earth.

rolled flints than the underlying Boulder-clay. Moreover, the number of chalk stones tells of reconstruction, as from the brown-weathered Boulder-clay such materials have usually been removed by dissolution.

The masses of Boulder-clay seen at the several points noted in the section, form portions of one bed which formerly extended along the front of the low cliffs, as represented on the Geological Survey map by Mr. Whitaker. Traces of the Boulder-clay may still be seen here and there at other points at the foot of the cliffs, where the modern beach-shingle lies in thin patches. Elsewhere it forms projecting banks, as it has withstood the ravages of the sea better than the Crag deposits, the fresh-water beds, or the modern loamy beach accumulation. That it forms part of the well-known chalky Boulder-clay of East Anglia, admits of no doubt. It contains, in addition to chalk and flint, fragments of Kimeridge shale with *Lucina minuscula*; also *Belemnites* and *Gryphæa arcuata*.

The age of the fresh-water bed is not clear. At first sight it resembles a mass of the Forest Bed series, reminding one of the black peaty bed and Rootlet Bed that overlie the Chillesford Clay at Kessingland and Runton.[1] Fossil evidence is needful to determine its age, for one must bear in mind the "post-Glacial" river-bed of Mundesley, the fresh-water bed found by Mr. Charles Candler over the Boulder-clay at South Elmham, near Harleston,[2] and that at Hoxne, with any one of which it is possible the Southwold bed may correspond.

Mr. Clement Reid, who has kindly examined some of the materials from the fresh-water bed, has identified *Planorbis complanatus*, *Valvata piscinalis*, *Sphærium corneum*, and *Pisidium pusillum*; also *Ranunculus aquatilis*, *Comarum palustre*, and *Ceratophyllum demersum*. As both mollusca and plants range from the Pliocene (Forest Bed series) to the present time, they afford no clue to the precise age of the deposit.

It would seem natural to compare this fresh-water bed with the "post-Glacial brick-earth" worked a little further north, and briefly described by Mr. S. V. Wood, jun., and afterwards by Sir J. Prestwich, who recorded the occurrence in it of *Elephas primigenius*.[3] An examination of the present sections in the brickyard showed no strata that could be correlated with the beds seen in the cliff; moreover, the deposits are separated by the intervening mass of Crag beds. I am thus obliged to leave the age of the fresh-water bed an open question. That it does not occupy an undisturbed hollow in the Boulder-clay, is shown by the synclinal arrangement of the layers in the fresh-water deposit; and this fact, together with that of the striking resemblance to the characters of the Forest Bed series, suggested transportation. Mr. Reid has, however, drawn my attention to a

[1] It is interesting to learn that Mr. J. H. Blake observed beds that might belong to the Rootlet Bed (Forest Bed series) at Easton Bavent.—Whitaker, "Geol. Southwold," p. 70.

[2] Quart. Journ. Geol. Soc., vol. xlv, p. 504.

[3] See Whitaker, "Geol. Southwold," p. 62.

somewhat similar feature in a peaty bed overlying Boulder-clay at Kelsey Hill, which he has attributed to the subsidence of the Boulder-clay through the slipping of underlying sand.[1] In the present instance it is possible that subterranean erosion may have produced the syncline.

The junction between the fresh-water bed and the Boulder-clay is marked by an irregular band of bedded loam, with chalk stones, flints, and other gravelly materials, and this junction-bed is from one to nearly four feet thick on the northern side.

The section of the fresh-water bed may be noted thus :—

	ft.	in.
Laminated peaty bed	2	6
Brown, grey, and greenish micaceous loam, with much ferruginous matter	8	0
Greyish loam, with fresh-water shells; and irregular pebbly layers of rolled and subangular flints (cemented into an iron pan),[2] with ochreous pebbles, bits of carbonaceous shale and lignite		

With regard to the Crag, several questions arise. Is it part of the true Norwich Crag, or does it belong to the Southwold Pebble-beds, which were regarded as of subsequent age by the late Sir Joseph Prestwich. Are the Southwold Pebble-beds the same as the Westleton Shingle?

The shells in this exposure at Southwold are mostly broken or comminuted. I could only recognize *Cardium edule, Cyprina islandica, Mya,* and *Littorina littorea.*

The general character of the strata, and their position, led me to group them as part of the Norwich Crag; and in this opinion I find support in Mr. Whitaker's description of the section formerly seen near by, but a little to the south, being about 250 yards NNE. of the coastguard station at Southwold; and support is also given in the list of shells there obtained by Mr. S. V. Wood, jun., and Mr. W. M. Crowfoot.[3]

The occurrence of shelly patches in the pebbly gravels elsewhere near Southwold has been noted by Sir Joseph Prestwich and Mr. Whitaker, and the subject has been further discussed by Mr. Clement Reid and Sir Henry Howorth.[4] In no case has any evidence been brought forward to show that these shell-beds do not belong to the Norwich Crag. No shells have been found in the Westleton Shingle of Westleton; and those which have been found near Southwold usually occur low down in the pebbly gravels, and may in all cases belong to the true Norwich Crag. I do not feel confident that the Southwold pebble-gravels, so well shown on Southwold Common and in the adjacent railway-cutting, belong to the horizon of the Westleton-beds of Westleton. They may well belong to the pebbly sands of the Crag seen in the north

[1] "Geology of Holderness," p. 74.

[2] Some masses of modern beach-shingle, plastered against the fresh-water bed, have also been cemented into an iron pan.

[3] "Geology of Southwold," 1887, pp. 61, 81, etc.

[4] Reid, "Pliocene Deposits of Britain," 1890, pp. 104, 201, etc.; Howorth, Quart. Journ. Geol. Soc., vol. li, p. 498.

cliff, Southwold. I have again had the opportunity of examining the fine sections at Westleton, where the shingle is imbedded in buff sands, and presents an aspect quite different from that of the Bure Valley Beds of the Norfolk area and from the Crag Series at Southwold. Following the beds to the cliffs at Dunwich, they are seen to rest on a mass of buff sands, more like Middle Glacial Sand than anything else.[1] Where gravels and sands of variable character and different ages come together there is abundant room for diversity of opinion, and those who peruse Mr. Whitaker's Memoir on the Geology of Southwold will find a clear statement of the facts and of the conflicting views with regard to their interpretation.

During my visit to Southwold in the summer of 1895, the Crag was well exposed at the base of the low cliffs at Easton Bavent, but, while collecting a number of fossils, only one form proved to be new to the locality, and that was a tooth of *Microtus* (*Arvicola*), the identification of which was kindly verified by Mr. E. T. Newton.

VII.—Notes on some Rocks from the Solomon Islands.

By W. W. Watts, M.A., F.G.S.; with notes by E. T. Newton, F.R.S.

[Communicated by permission of the Director-General of the Geological Survey.]

AFTER he had published his account of the geology of the Solomon Islands,[2] Dr. Guppy was good enough to present to the Museum of Practical Geology a series of typical specimens showing the chief varieties of calcareous and argillaceous deposits met with in the islands. This collection includes rocks, washings, picked organisms, with a few microscopic slides, and it constitutes a series very valuable for reference.

During the surveying of the islands by the Admiralty in 1893–5, Lieut. A. Waugh has been able to collect many specimens of volcanic and sedimentary rocks, which have also been presented to the Museum. As some of these were collected at localities not visited by Dr. Guppy, and as a few of the types have not been previously described from the islands, it may be worth while to communicate to the Geological Magazine a short account of Lieut. Waugh's collections.

I.—*The Sediments.*

The classification adopted by Dr. Guppy for these rocks may be briefly summarized as follows. For further details the reader is referred to the original paper.

A. Volcanic débris mixed with organic remains and resembling the muds now forming round oceanic, volcanic islands.

(a) 5–20 per cent. of $CaCO_3$, minute foraminifera, and a few mollusca.

[1] See H. B. W., Geol. Mag. 1882, p. 455.

[2] "The Solomon Islands, their Geology, General Features, and Suitability for Colonization," by H. B. Guppy, M.B., F.G.S. (London, 1887): Trans. Roy. Soc. Edin., vol. xxxii (1887), p. 545.

(*b*) 30–35 per cent. of $CaCO_3$, pteropods, gasteropods, lamellibranchs, foraminifera, etc.

(*c*) 60 „ „ fragments of corals, algæ, lamellibranchs, and a few foraminifera.

(*d*) Coarse rocks made of fragments of volcanic and coral rocks in rounded grains.

B. Organic constituents most abundant, 66–96 per cent. of $CaCO_3$; volcanic materials quite subsidiary.

(*e*) Coral rocks with the original structures more or less obliterated, becoming drusy, saccharine, or compact.

(*f*) Coral rocks with algæ, fragments of mollusca, corals, and echinoderms; interstices filled with foraminifera and small calcareous organisms.

(*g*) Fawn-coloured, crystalline limestones made of the coral ooze of lagoons.

(*h*) Chalk-like coral limestones; corals, mollusca, algæ, etc.

(*i*) Foraminiferal limestones chiefly made of the tests of pelagic and bottom-living foraminifera.

C. A deep-sea clay.

The greater part of Lieut. Waugh's collection falls into these classes, as will be seen from the following account of the chief specimens.

A (*a*) *Foraminiferal mud.*—South coast of Tetapari Island (F. 303), "from between the blocks of coral." This resembles the earthy foraminiferous deposit described from Ugi and Treasury Islands by Dr. Guppy. It consists of fine argillaceous material, a few chips of volcanic minerals, and abundant foraminifera, some cells of which are empty, but others filled with a brown deposit insoluble in acid. On dissolving the tests in weak acid an earthy skeleton would sometimes persist for a moment, as though the perforations had been filled with some fragile, insoluble substance. A few sponge spicules were seen in the residue. Mr. Newton says that *Globigerina* is the most abundant foraminifer.

B (*e*) Coral rocks are of very common occurrence in New Georgia, and have been collected from the following localities on that and the neighbouring islands—Viru harbour, the south coast, Bili village, and Mbulo Island. They also occur on Ugi Island and on the mainland of Florida Island. They were found at the sea-level as well as at heights up to 130 feet, and as much as a mile inland. They correspond to Dr. Guppy's description, and need no further remark.

B (*f*) These might be called "mixed coral rocks." They are clastic limestones made up of broken bits of organisms, calcareous mud, and a small amount of terrigenous or volcanic material. They occur on the mainland of Florida Island, one at the water-level (F. 278), the second at 20 feet (F. 281), and the third at 40 feet, above it (F. 279), on the floor of a cave 20 feet below the surface on the island of Ereru, inside the lagoon (F. 272), and at the Charapoana entrance of the great barrier reef of New Georgia (F. 290). I append Mr. Newton's description of the rocks—

"These five specimens are hard limestones varying from fine, close-grained to coarsely cavernous rock. The first specimen from Florida Island (F. 278) has the finest, and the third (F. 279), the coarsest texture of the three. Under the microscope they are seen to be composed of similar materials, namely, fragments of nullipores, corals, and foraminifera, the last-named being chiefly in the finer material filling in the larger cavities. In the first (F. 282) of the other specimens the rock is much coarser and more cavernous than in the three above noticed, and some of the surfaces are covered by a calcareous coating (stalagmite?). Under the microscope, pieces of molluscan shells, corals, and possibly spines of echinoderms, were detected, as well as large foraminifera (*Amphistegina*, etc.). This rock closely resembles Dr. Guppy's figure.[1] The last of these coral rocks (F. 290) was found six feet above high-water mark. It is the coarsest rock of the series, and is chiefly formed of nullipores and corals, the cavities being filled in with débris, in which are foraminifera and other small organisms; few or no sponge spicules were detected in any of these fine coral rocks."

B (*h*) Under the name of *chalky coral rock*, Dr. Guppy describes a set of limestones which "in the general composition resemble the rocks of the second group of coral limestones [B (*f*)], but differ conspicuously in their chalk-like appearance and in being more friable." Microscopic examination of one of Dr. Guppy's specimens from the Shortland Islands bearing this designation (F. 299), does not accord exactly with this general description. The rock shows that minute crystals of dolomite are of frequent occurrence, and a chemical test reveals a small proportion of magnesia. This fact has already been made known by Dr. Guppy in a rock which corresponds closely with the following description.[2] Of this rock Mr. Newton remarks as follows:—"Under the microscope, nullipores are very distinct, and there is evidence that other organisms have been present, such probably as would make up an ordinary 'mixed coral rock,' but these are so decomposed as to leave mere traces of their original shape. It is worthy of remark that the nullipores seem to be able to resist the action which has caused the alteration of this rock better than any of the animal organisms, and perhaps this may be due to the different state of the carbonate of lime of which they are composed."

Specimens from the south coast of Mbulo Island (F. 297) and from the southern coast of New Georgia, on the other hand, appear to correspond with Guppy's general description. They are friable, white, chalky limestones, containing abundant relics of organisms, which are mostly in a fragmentary condition. They are set in a fine calcareous mud, in which I have seen no evidence of dolomite. Mr. Newton adds that the slide contains "pieces of corals, nullipores, foraminifera, molluscan shells, etc., and is, in fact, one of the 'mixed coral rocks' in a somewhat friable condition."

We now proceed to describe a few types of rocks not included in Dr. Guppy's classification.

[1] Trans. Roy. Soc. Edin., vol. xxxii (1887), pl. cxlv, fig. 3.
[2] "The Solomon Islands, their Geology," etc., p. 74.

At Bili village and on the south coast of New Georgia (F. 296) *tufaceous limestones* occasionally occur on the face of the cliffs. They are of spongy texture, and are evidently the result of springs percolating through coral rock and other calcareous deposits. Under the microscope they show the usual banded structure due to the deposit of minute calcite crystals.

At the western end of Tetapari Island (F. 304) was found a deposit of *volcanic mud* devoid of calcareous matter. Very little of this specimen is soluble in acid, and what is left is like the residue left on acting on the foraminiferal mud of the same island with acid. It is evidently a volcanic mud which happens to be almost devoid of organisms, either from the loss of them by solution, or more likely, as the rock is fairly compact, from the circumstances of its deposition.

On a hill summit, about a mile inland, on Ugi Island, Lieut. Waugh found a curious *rotten-stone* (F. 302). Fragments of coral showing structure were found in the same locality, so that the rock is almost certainly the result of the operation of solution on a foraminiferous mud like that already described in this note and like those described by Guppy in this island. The rock is cavernous, the hollows revealing the shapes of dissolved foraminifera. Very little of it is soluble in acid, and the residue consists of fine clay with a few chips of volcanic minerals, such as felspar, augite, and olivine. Mr. Newton remarks that "In one instance a foraminifer was itself preserved in some material which was not affected by acid."

Two examples of *siliceous deposits* were found—one in Florida Island, about 20 feet above high water-level (F. 280), and one on Gavutu Island, just opposite, at 10 feet above the same datum (F. 285). They are white or cream-coloured, banded rocks, rough and siliceous in feel, light in weight, and with one or two coarser layers which contain a preponderance of chips of volcanic minerals that are present in some quantity throughout the rock; these minerals include felspar, augite, hornblende, and olivine, with a little quartz. I append Mr. Newton's full description—

"A fine-grained, friable rock, which does not effervesce with acid, was examined both in section (F. 280) and also as a powder. Under the microscope it was found to contain numerous organic remains, chiefly the spicules of tetractinellid sponges, and these of many different forms, with fragments which indicate the presence of radiolaria. No foraminifera were detected.

"F. 285 is another specimen of a very similar rock. Like the last, it did not effervesce with acid, and under the microscope very few organisms could be found; but those that were present were similar sponge spicules and possibly radiolaria.

"It will be evident that the conditions under which these two rocks were formed were quite unlike those necessary for the formation of the coral rocks, and they may possibly indicate somewhat deeper water. The deep-sea clay mentioned by Guppy [1] is quite unlike these specimens, for that is somewhat calcareous and contains but few sponge spicules."

[1] Trans. Roy. Soc. Edin., vol. xxxii, p. 558.

II.—*The Igneous Rocks.*

The igneous rocks collected by Lieut. Waugh appear, with two probable exceptions, to be the products of recent volcanoes. Some of them are *andesites* corresponding very closely with those in the large series deposited by Dr. Guppy in the British Museum and described by the late Mr. T. Davies. By the kindness of Mr. Fletcher and Mr. Prior, I have been allowed to look over the slides of these rocks, and I desire to record my hearty thanks to these gentlemen for the privilege accorded to me. Some others of the rocks collected by Dr. Guppy are at present lodged at the Royal College of Science, and they have been examined by Prof. Judd. The latter has been so kind as to allow me to study his slides and specimens. He has not only given me every possible facility for working at them, but he allowed me to see his notes on the specimens, for which I desire to thank him cordially. His specimens have, however, little bearing on the present communication, except that he recognized orthorhombic as well as monoclinic pyroxene in some of the andesites. The plutonic rocks of Prof. Judd's collection are not represented at all amongst those which have been submitted to me from New Georgia and elsewhere.

There are, however, in New Georgia a number of much more basic rocks, *porphyritic olivine-basalts*, which, from the state of preservation of their minerals, are almost certainly recent volcanic products. No rocks quite like them are to be found in the British Museum collection or in Prof. Judd's series.

The occurrence of these two types of volcanic rocks in New Georgia confirms Dr. Guppy's surmise that the island would be found to be volcanic in structure. Although he was unable to visit it, he inferred from its geographical position that it would be made up of recent volcanic products, as it was situated on the important volcanic line proceeding from Bougainville Island.

The igneous rocks may be classed as follows :—

(1) Porphyritic olivine-basalts with very little porphyritic felspar.
(2) ,, ,, ,, ,, olivine.
(3) Augite-andesites.
(4) Hypersthene-andesites.
(5) Hornblende-andesites.
(6) Augitic trachytes.

(1) *Porphyritic olivine-basalts* with very little porphyritic felspar appear to be very common in the south-east of the island. One specimen comes from the summit (F. 289) and one from the foot (F. 287) of the Karu Mahimba Range, and three others from or near a river which drains the southern spurs of that range (F. 284, 292, and 293). They are dark-grey rocks weathering brown, and they show on the fractured surface fresh porphyritic crystals of green olivine and black augite, but no felspar. Under the microscope the augites are seen to be often aggregated into groups; the individual crystals are sometimes zoned, and they contain fair-sized patches of magnetite. They are slightly pleochroic, in colours of pale yellow

to pale-yellowish green. The olivine is frequently idiomorphic and tends to occur in single individuals rather than in groups; and although usually quite fresh, it has often a brown border, and is sometimes converted entirely into the substance known as iddingsite. Large grains of iron-ore are generally present, but phenocrysts of felspar are small and scarce, and they tend to graduate down to the smaller crystals of the ground-mass; the extinctions appear to indicate that this felspar is labradorite. The ground-mass consists of augite granules, iron-ore dust, and felspars in the form of stumpy prisms, laths, or needles, all of which are striated, with a very little brown mica. The felspars usually show flow-structure, and a little interstitial glass can be made out. One variety of this rock (F. 289) contains a rather larger number of labradorite phenocrysts, which are, however, not large in size.

(2) *Porphyritic olivine-basalt* with abundant phenocrysts of felspar occurs at the summit of Dubatina Mountain (F. 295) and at the summit of Kutelike Mountain (F. 283), portions of ranges which run north and south respectively from the Karu Mahimba Range. The rocks are rather darker in colour than the last type, and they show needle-like, twinned crystals of felspar on their broken surface, with occasional dark crystals of augite. The weather appears to penetrate deeply into them, and one of the specimens is coated with a thick brown crust. The principal phenocrysts consist of a felspar, apparently labradorite, with a high refractive index; usually it has a clear border which extinguishes at a lower angle than the core, and into this the twin striation penetrates. The augite is like that already described, but it is beautifully zoned, and the olivine which is not very abundant, is in small grains more or less replaced by serpentine. The ground-mass consists of stumpy felspars, augite granules, and magnetite dust, and it does not appear to contain any unaltered glass. In one specimen of this rock (F. 295) the felspar is commonly in cruciform twins, and the crystals possess cores or belts of minute inclusions with a border of clear felspar.

(3) The *augite-andesites* require little notice, as most of them are identical with those described in Dr. Guppy's book. One specimen (F. 286) was collected near the sea-level, and one (F. 291) at the summit (672 feet) of Marovo Island, which is practically the south-eastward extension of New Georgia. The rocks are light grey in colour, with an irregular fracture, and a rather horny surface which shows phenocrysts of felspar. No olivine is present, and augite is by no means so common as in the basalts. The principal phenocrysts are of plagioclase felspar, either as carlsbad or albite twins, the latter giving such extinctions as to show that the felspar is somewhere between andesine and labradorite. The interior of the felspars often exhibits a *moirée* structure, which is not observable in the outer shell. The ground-mass is made of elongated felspar microlites giving extinctions proving that they belong to the oligoclase-andesine series, with augite granules and a small quantity of iron-ore dust set in a brown glass, which passes locally into bright orange patches with a weak aggregate polarization, apparently a form of palagonite.

(4) Only one sample of *hypersthene-andesite* has reached me; it is from a rounded pebble found 40 feet above high-water level on a small island on the reef in the Gizo group (F. 244). It shows glassy felspars in a grey andesitic matrix. The section exhibits zoned plagioclase felspars, which belong to the more acid division of the labradorites, a few green hornblendes, small augites, and fairly abundant crystals of hypersthene, imbedded in a brown-tinted glass containing a few felspar microlites and black trichites in such plenty as to give the glass its brown colour. In the British Museum collection I have noticed similar hypersthene in the andesites from the Shortland Islands, and Prof. Judd has noted its occurrence on Simbo or Narovo Island.[1]

(5) The single example of *hornblende-andesite* comes from the summit of Evorai Mountain, on the north coast of New Georgia (F. 294), and is much decomposed. It is of a dirty grey colour, and has scattered through it large porphyritic crystals of hornblende, some of them being half an inch long. With a lens, felspar crystals and smaller ferro-magnesian minerals can be seen. The fine collection in the British Museum contains a large number of rocks of similar microscopic character, and in this collection every gradation from hornblende to augite-andesite can be studied. A specimen in Prof. Judd's collection from the north part of Piedu Island is also like this rock in macroscopic aspect. Plagioclase felspar, a labradorite, with zoning and multiple twinning, is abundant as a porphyritic constituent. The hornblende is deep brown in colour, and usually has an opaque black border, which sometimes extends into the crystal or even replaces the whole of it. Iron-ore granules and a few crystals of augite are present, and there are also pseudomorphic patches of chlorite and magnetite which appear to replace the latter mineral. The ground-mass is of minute felspar crystals, matted together in a clear glass, which also contains iron-ore dust and serpentinous replacements of a ferro-magnesian mineral.

(6) *Augitic trachyte.*—A remarkable rock, which probably belongs to this class, occurs on the slopes of Kutelike (F. 288). It is not like the other rocks, nor, indeed, is it quite like any one with which I am acquainted. It is light grey and granular in aspect, traversed by innumerable minute, joint fissures, and exhibiting on the broken surface crystals of black augite and occasional felspars imbedded in a white matrix. Under the microscope the bulk of the rock is seen to be made up of small crystals of felspar, which are rhomboidal in section, and are almost entirely devoid of twinning, except now and then on the carlsbad plan. They are beautifully zoned, the outside extinguishing at a lower angle than the interior. The refractive index, where it can be determined, appears to be higher than that of canada balsam. On placing the powdered rock in a diffusion column of methylene iodide, about half the felspar floats in liquid with a density of 2·57, proving that a good deal of the felspar is orthoclase. Another portion floats at 2·62. This seems to indicate that orthoclase and albite are present in about equal proportion, and it is quite

[1] "The Solomon Islands, their Geology," etc., p. 44, footnote.

possible that the crystals possess cores of albite surrounded by zones of orthoclase. A striated felspar has been found in a slide prepared from another rock from the same general locality. A few phenocrysts of green augite are present, and also one or two of hornblende. The ground-mass is obscure, but it appears to be made up of a smaller generation of similar felspars, augite prisms, and magnetite with little or no glass.

Only two other rocks remain for description. One from Vongi Mountain, on an island south-east of New Georgia, is a porphyritic *olivine-basalt* (F. 243) in which the minerals are somewhat altered, so that the rock may possibly belong to the rather older group referred by Mr. T. Davies to the diabases. A similar rock, but one in which the presence of olivine cannot be absolutely demonstrated, is that from Gizo Island (F. 245). The felspars are much decomposed, and the augite somewhat altered; the rock is a porphyritic basalt, which contains pseudomorphs after olivine or hypersthene—which, I cannot say.

III.—*Summary.*

The general result of the investigation of this collection is to show that New Georgia consists chiefly of volcanic rocks belonging both to the andesitic and basaltic division, and probably of recent date. At the edge of the island organic rocks have been deposited in connection with the great barrier reef, and no organic rocks have yet been detected at any considerable distance inland.

The chief rocks from Tetapari Island and the Florida group are made of organic material mixed with volcanic mud, the latter sometimes entirely excluding the former substance. Occasionally the calcareous matter is leached out of a rock of this nature, leaving a rotten-stone behind which can only be distinguished from a pure volcanic mud by its open texture and its casts of organisms. Another result of this action is the formation of tufas. On and near Florida Island there also occurs a peculiar deposit of siliceous material, made of the remains of sponge spicules and radiolarian tests.

Guppy notes that the interstices of coral rock are filled in with the relics of foraminifera and other small calcareous organisms. On Tetapari Island this foraminiferal material occurs in considerable quantity between the coral blocks in the limestone of the shore.

VIII.—Analysis of a Spherulite and the Matrix in a Natural and an Artificial Rock.

By H. H. F. Hyndman, B.Sc.; with Notes on their Microscopic Structure by Prof. T. G. Bonney, D.Sc., LL.D., F.R.S.

THE differences in chemical composition between spherulites and the matrices which contain them have been determined by many analysts. Michel Lévy, in a long and comprehensive paper,[1] quotes some former analyses by Delesse,[2] comparing them with his own, which they closely resembled. Lagario[3] gives many analyses

[1] Bull Soc. Geol. France, v, 3rd series, p. 232 (1877).
[2] Ann. des Mines, xvii, 4th series, p. 116 (1850).
[3] See Teall's "British Petrography," p. 397.

which are especially valuable, as he compares results from acid with those from intermediate and basic rocks, and finds a distinct difference between them. The relations of these results will be briefly considered at the end of the present paper.

I. The Natural Spherulitic Rock.

The specimen examined was obtained by Prof. Bonney at Boulay Bay, Jersey, the noted locality for "pyromerides"; it did not, however, come from a rock *in situ*, but was a loose, somewhat rounded block on the shore, measuring about eight inches across, and the spherulites are smaller than in the ordinary pyromeride. Still, he had no doubt that it had once formed part of the rhyolitic mass, for this exhibits many variations. The matrix is of a pale yellowish-green colour, something like sea-water, but looking rather opaque. The spherulites are reddish, sometimes pale red, becoming whitish towards the outside, sometimes with an outer zone of darkish purple red. They generally exhibit some indication (occasionally distinct) of radial structure.

Under the microscope the matrix is cracked and sometimes distinctly perlitic. The green tinge is evidently caused by a mineral which occurs in minute plumes, irregularly scattered, giving fairly high colours with crossed nicols, and belonging probably to the chlorite group. Microliths and granules, mostly ferrite, are not rare. With crossed nicols the matrix is seen to be devitrified, a mosaic of somewhat irregularly-shaped minerals, varying in size in different parts and affording rather low tints; quartz is certainly present, as well as felspar, but as the one mineral is often rather dirty, and the other is slightly decomposed and untwinned, it is not easy in all cases to distinguish them.

The spherulites, though the boundary is generally sharply defined, are less regular in structure than one would have anticipated; they are not unfrequently cracked and traversed by veins of chalcedonic quartz. Portions sometimes had been displaced before the matrix became solid. The outer part often exhibits a kind of lobate growth, which seemingly is developed from the surface inwards, comparable with that of a nullipore like *lithothamnion*, as seen in a slice of limestone. A radial structure is perceptible, though not very distinct, as in axiolites. Sometimes, however, this structure is exhibited in the usual way, throughout the outer zone, and is then replaced (for a space) by one less regular. The interior often presents a more distinctly radial structure, but it is minute, and crowded granules of clear quartz sometimes occur.

When the rock was sampled for analysis, it was found possible in many cases to break the spherulites out complete; only those which were perfect in this way were used. To obtain a good sample of the matrix was much more difficult. At first sight the rock left after breaking away the spherulites appeared fairly homogeneous, but on closer inspection it was difficult to find even a small portion which did not contain part of an incipient spherulite. The end was attained by carefully breaking away small pieces from the rock just

surrounding the better-formed spherulites. This material possessed the sea-green colour mentioned above, and when finely powdered was white, while the spherulites gave a reddish powder. It was found that quite a minute portion of a partly-formed spherulite produced a distinct tinge. The results were as follows:—

	Spherulite.		Matrix.
SiO_2	73·23[1]	...	78·40[1]
Bi_2O_3 and oxides resembling it ...	0·51	...	0·58
Al_2O_3	11·45	...	8·81
Fe_2O_3	4·50	...	...
Cu O and oxides resembling it ...	0·30	...	trace
Fe O	...	...	4·02[2]
Ni O	trace	...	0·29
Ca O	0·38	...	0·57
Mg O	0·02	...	0·20
K_2O	2·77[3]	...	2·62
Na_2O	5·14[3]	...	3·06
H_2O	0·81	...	1·53
	99·11		100·08

Oxygen ratio[4]—

	Spherulite.		Matrix.
SiO_2	39·05	...	41·81
Bi_2O_3	·05	...	·06
Al_2O_3	5·33	...	4·10
Fe_2O_3	1·35	...	...
Cu O	·06	...	...
Fe O	...	...	·88
Ni O	...	...	·06
Ca O	·11	...	·16
Mg O	...	...	·005
K_2O	·47	...	·45
Na_2O	2·10	...	·79
H_2O	·71	...	1·34
R O : R_2O_3 : SiO_2 ...	2·74 : 6·73 : 39·05		2·345 : 4·16 : 41·81
Including H_2O	3·45		3·68

The method of analysis employed for all except the alkali metals was thorough fusion in a platinum crucible with mixed alkaline carbonates. The spherulite gave a light greenish mass, and the matrix a still lighter one; they both dissolved easily in dilute hydrochloric acid, and were evaporated to dryness twice with this acid. The sulphuretted hydrogen precipitate was brownish black in both cases. After the separation of the aluminum and iron hydroxides, the nickel was precipitated by ammonium sulphide, and the amount being small it was weighed as sulphide. The double determinations of the silica were obtained by treating the preliminary qualitative examination as quantitative, until the silica had been separated.

In each case the powdered rock, spread out on a watch-glass, was heated for some hours, to about 110° F.; the loss of weight was small, only amounting to ·36 per cent. in the matrix. The powder was

[1] Mean of two.

[2] All the iron is calculated as Fe O.

[3] Another calculated as $Na_2O = 7·48$.

[4] The oxygen ratio is equal to $\frac{\%\text{ oxide in rock} \times \%\text{ oxygen in oxide}}{100}$

then transferred to a platinum dish and heated over the blowpipe, the loss of weight being taken as equal to the combined water. The iron was determined in each case by the titration of an aliquot part of the solution, the result being calculated to Fe_2O_3 in the case of the spherulite, and to FeO in that of the matrix; since a preliminary test showed that this contained a considerable quantity of FeO, with probably a little Fe_2O_3.

The alkalies were determined by heating the finely-powdered rock with ammonium chloride and calcium carbonate, treating with water and precipitating the bases from the solution; the potassium was then separated, and weighed as potassium platino-chloride.

In the analyses of typical felspars, taking the Al_2O_3 as unity, the other constituents occur in the following proportions:—

	Orthoclase.	Albite.
Al_2O_3	1	1
SiO_2	3·49	3·50
K_2O	0·90	—
Na_2O	—	0·60

If, then, in the above analysis of the spherulite we suppose the K_2O to be present in orthoclase and the Na_2O in albite, we find, using these proportions, that the alumina is almost exactly the amount required, and that about 28·5 of the SiO_2 remains: that is to say, the spherulite must consist almost entirely of albite, orthoclase, free quartz, and some ferric oxide, and there is, roughly speaking, three times as much albite as orthoclase, the felspars making up rather less than two-thirds of the mass.

In the matrix the felspars occur in smaller quantity and in more nearly equal proportions (the albite still dominating), and there is a larger amount of free quartz.

Both these analyses could find parallels among the published bulk-analyses of felsites or volcanic glasses. Both (before devitrification) would represent dacites, but the matrix has the nearer relation to the rhyolites. These analyses accord with the conclusions of Lagario, especially in the larger proportion of soda in the spherulite, and in most of the cases given by him the silica percentage is higher in the matrix.

The following analyses of a spherulite and of the matrix are given by Michel Lévy (Bull. Soc. Geol. France, v, 3rd series, p. 248).

	Spherulite.	Oxygen ratio.	Matrix.	Oxygen ratio.
SiO_2	56·90	30·34	45·08	24·04
Al_2O_3	19·24	8·98	22·17	10·35
FeO	6·28	1·39	12·55	2·79
CaO	9·41	2·68	6·62	1·87
MgO	5·80	2·32	13·00	5·20
K_2O	0·59	0·10	0·65	0·11
Na_2O	4·16	1·07	1·59	0·41
	102·38		101·66	
Loss on heating	2·00		5·27	
RO : R_2O_3 : SiO_2	7·56 : 8·98 : 30·34		10 40 : 10·35 : 24·04	

These analyses differ considerably from those given above. Here not only the silica is greater in the spherulite, but also the lime and alkalies: this gives a perfectly different relation to that found in the above analyses, as shown by the ratio of the oxides. The large quantity of magnesia may be responsible for the difference.

II. The Artificial Spherulitic Rock.

The specimen analyzed had been given to Prof. Bonney by Mr. F. Siemens, of Dresden. It was a bottle glass of a rich resin brown tint (such as is often seen in hock bottles), and the spherulites are of a pale-cream or yellow-ochre colour.[1] Under the microscope the glass exhibits only the very palest tinge of brown, and is almost free from microlithic enclosures; these, as far as they occur, being minute specks, like a dark dust. Crystallites, however, project from the border of the spherulite for a short distance into the glass. The spherulite consists[2] of (*a*) ferrite in small irregular patches; (*b*) an acicular clear mineral, clustered and radiating, forming the mass of the spherulite; (*c*) tufts consisting of a few clear acicular crystallites, diverging like a bundle of sticks loosely tied in the middle. With ordinary light the radial structure appears to dominate, zoned by concentric, more opaque bands, but with crossed nicols the tufted structure completely overpowers it in certain clearer-looking bands towards the exterior, and is more or less conspicuous in all the outer part of the spherulite, except for about the last one-thirtieth of an inch, where the radial structure is almost exclusively present. The feathery exterior of the spherulite appears to be formed of microliths grouped fern-leaf fashion; two sets of crystallites diverging at angles of about 50° from a central stem. The crystallites in the tufts certainly extinguish obliquely, though the angles are not large, perhaps within about 12° of the edge. It is difficult to ascertain the extinction of the radially grouped crystallites, but probably this also is oblique.

Analyses.

	Granite.[3]	Spherulite.	Matrix.
SiO_2 ...	69·30	58·60	56·89
Bi_2O_3 ...	...	0·42	trace
Al_2O_3 ...	17·70	13·33	10·21
Fe_2O_3 ...	1·10	...	3·13[4]
Cu O ...	...	trace	2·47
Fe O ...	...	2·76	...
Ca O ...	1·60	8·30	1·71
Mg O ...	0·13	0·28	1·06[5]
K_2O ...	3·45	5·62	6·20
Na_2O ...	5·20	10·31	17·81
	98·48	99·62	99·48

[1] In making this glass the principal material employed is a granite or granulite. See President's Address, Quart. Journ. Geol. Soc. 1885, Proc., pp. 88, 90.

[2] The description is written from a new slice, which is thinner than the one used in 1885.

[3] *Ut suprà.*—Of two analyses given of the original granite, the most likely one of the two is chosen.

[4] The iron here is probably too high.

[5] Probably contains some lime.

Oxygen ratio—	Spherulite.	Matrix.
SiO_2	31·25	30·34
Bi_2O_3 and oxides resembling it ...	·04	...
Al_2O_3	6·21	4·76
Fe_2O_3	...	·94
CuO	...	·50
FeO	·61	...
CaO	2·37	·49
MgO	·11	·42
K_2O	·95	1·05
Na_2O	8·66	4·60
$RO : R_2O_3 : SiO_2$	7·06 : 5·70 : 30·34	6·7 : 6·25 : 31·25

The matrix, on fusion with mixed alkaline carbonates, gave a bright blue-green mass, and this dissolved to a yellow liquid on solution in dilute hydrochloric acid. The percentage of iron in the matrix appears to be high, and cannot be correct unless iron came in as an impurity in the materials, or was added for colouring purposes. The copper, which practically remains in the glass, has been undoubtedly added for this reason. The general processes of analysis and the method of determination of the alkali metals were carried on in the same manner as in the former analyses.

It is not easy to interpret the bulk-analysis of the spherulite, and we must bear in mind the possibility that, as it is an artificial product, the constituent minerals may not correspond with any that occur in nature. Comparing with the analysis of the original granite, it is evident that some lime, potash, and a considerable quantity of soda must have been added in some form or other. A rough calculation, however, indicates that if the potash were present as orthoclase, and some of the soda as albite, this would use up the alumina and about seven-tenths of the silica; the remainder of this, with the rest of the soda, the lime, magnesia, and iron protoxide, might form a mineral allied to the soda pyroxenes.

The silica percentage of the granite glass is comparable with that in the intermediate rocks, in which Lagario [1] has shown that the matrix tends to become a mixture of quartz and orthoclase. The analysis given above does not agree with this, as the matrix has less silica and more soda than the glass, but corresponds fairly well with one of Dumas' quoted by Professor Bonney in his presidential address [2]; but the ratios of the oxides are very different.

	Crystallized part.	Vitreous part.
SiO_2	68·20	64·70
Al_2O_3	4·90	3·50
CaO	12·00	12·00
Na_2O	14·90	19·80
	100·00	100·00

Oxygen ratio—	Crystallized part.	Vitreous part.
SiO_2	36·37	34·50
Al_2O_3	2·20	1·59
CaO	3·43	3·43
Na_2O	3·84	5·11
$RO : R_2O_3 : SiO_2$	8·54 : 1·59 : 34·50	7·27 : 2·2 : 36·37

[1] *Loc. cit.* [2] *Loc. cit.*

The higher percentage of soda in the glass is probably due to the artificial conditions; there is a large overdose of soda, which cannot crystallize. Michel Lévy, in the analyses given above and in others, finds that the silica percentage is greater in the spherulite, which is exactly contrary to the result obtained by Lagario. In this it will be seen that one of my analyses agrees with one authority, and the second with the other. It is evident that the differences between the matrix and spherulite may be small or large and one way or the other, so that at present it is not possible to prove any constant relation between them.

The following papers will be found useful for reference, including those given above:—

Michel Lévy.	Bull. Soc Geol. France, sér. 3, t. iii, p. 199; sér. 3, t. v, p. 232. Ann. des Mines, sér. 7, t. viii.
Delesse.	Ann. des Mines, sér. 4, t. xvii, p. 116. Mém. Soc. géol., sér. 2, t. iv.
Bonney, T. G.	Quart. Journ. Geol. Soc. 1885, Proc., pp. 88 and 90.
Potier.	Bull. Soc. Geol. France, sér. 2, t. v.
Wallerant.	Bull. Soc. Geol. France, sér. 3, t. xvi, p. 927; (Note on large Variolite), sér. 3, t. xvii, p. 447.
Rosenbuch.	Zeitschrift der deutschen geologischen Gesellschaft, t. xxviii.
Lagario.	See Teall's "British Petrography," p. 397.

IX.—On a new British Rock containing Nepheline and Riebeckite.

By T. Barron, A.R.C.S.

Introduction.

THE mineral riebeckite was first discovered by Professor T. G. Bonney[1] in 1882, who, in a paper to the Royal Society describing a series of rock-specimens from the island of Socotra, noticed the occurrence in a granite of a mineral which, though presenting characters common to the hornblende group, he referred doubtfully to tourmaline.

Four years later Oebbeke[2] described a mineral from the island of Sikoku, Japan, which showed intense colour and pleochroism, but differed in other respects from glaucophane, to which he referred it. The following year Professor A. Sauer,[3] of Leipzig, in examining a series of specimens collected by Dr. E. Riebeck from the island of Socotra, noticed the blue mineral described by Professor Bonney. Having isolated and analyzed it, and determined its optical properties, he placed it among the amphiboles, naming it riebeckite. In the same year Rosenbusch[4] found a peculiar variety of hornblende in a syenitic lamprophyre, which agreed in its optical properties with the mineral described by Sauer.

In 1888 Professor Bonney[5] described "a peculiar variety of

[1] Phil. Trans., vol. clxxiv (1883), p. 283.
[2] Zeitschr. für Kryst., vol. xii (1886), p. 285.
[3] Zeitschr. der Deutsch. geol. Gesellsch., vol. xl (1888), p. 138.
[4] "Die massige Gesteine," Bd. ii (1886-7), p. 312.
[5] Mineralogical Magazine, vol. viii (1888), pp. 103, 169.

hornblende from Mynydd Mawr, Carnarvonshire," which resembled the Socotra mineral very closely in its general characters. He, however, referred it with some hesitation to arfvedsonite. In the same year Mr. A. Harker,[1] who had been studying this same rock independently, referred the blue mineral to riebeckite. The following year two other localities were added to the list of places in which it occurs. It was described in a granulite from Corsica by M. Urbain Le Verrier;[2] and in a rock of the same description from Colorado by Lacroix.[3] In 1891, Mr. J. J. H. Teall[4] recorded the occurrence of riebeckite in a micro-granite from Ailsa Craig. The following year it was described in a granitite from Southern Sikkim, India, by Mr. T. H. Holland.[5]

Riebeckite has also been described by Professor Grenville A. J. Cole,[6] from eurite-pebbles collected from the glacial drift of the Isle of Man and Moel-y-Tryfaen; and later at Greenore,[7] near Carlingford, Ireland. Professor Sollas[8] has also described it from the glacial drift at Greystones, co. Wicklow.

The object of this present paper is to add one more locality to the list of places from which riebeckite has been recorded, and to describe a rock in which nepheline is associated with riebeckite—a combination which has not hitherto been recorded.

Occurrence in the Field.

The area from which the rocks to be described were collected, may be seen by referring to quarter-sheet No. 25 of the Geological Survey of Scotland. The specimens were obtained from three hills in the valley of the Tweed, two of which (the Eildons) lie to the west, and the other (Black Hill) lies to the east of that river. Viewed from the east, these three hills stand out boldly from the surrounding country, forming a conspicuous landmark. They are isolated pieces of what was once a continuous mass of lava, which, by the action of disintegrating agents, has been cut into ridges having a general trend east and west. That ice has played an important part in the configuration of this district, may be seen by a glance at the disposition of the ridges and valleys; and as confirmatory evidence I have found glacial striæ on the rocks of the Black Hill. But the lava has not only been cut into ridges lying east and west; it has also been breached by the Tweed in a southerly direction. In this way the Eildon Hills have been separated from the rest of the mass. The eastern side of the Tweed valley is formed at this point by the escarpment of the Old Red Sandstone, capped by igneous rock; and it is part of this escarpment which forms the base of the Black Hill. The opposite side of

[1] Geological Magazine, Decade III, Vol. V (1888), p. 455.
[2] Comptes Rendus de Acad. des Sciences, tome cix (1889), p. 38.
[3] *Op. cit.*, p. 39.
[4] Mineralogical Magazine, vol. ix (1891), p. 219.
[5] Records, Geol. Survey of India, vol. xxv, pt. 3, 1892.
[6] Mineralogical Magazine, vol. ix (1891), p. 222.
[7] Nature, vol. xlvii, p. 464.
[8] Proc. Geol. Assoc., vol. xiii (1893), p. 118.

the valley is less steep, and is bounded by the Eildon Hills, which are also formed of a base of Old Red Sandstone capped by igneous rock.

The junction between the Old Red Sandstone and the igneous rock is well seen in a quarry on the south side of the Black Hill. It is marked by a layer of hard, white, siliceous rock twelve inches thick, which, as will be shown later, has undergone some alteration by contact with the lava. Underneath this layer, the sandstone is soft and friable for several feet, but gradually passes into hard sandstone. In this soft rock, scales of *Holoptychius* are found, proving the rock to be of Upper Old Red Sandstone age.

The character of the rock in the three hills from which the specimens were collected, is rather variable. The most westerly hill (Middle Eildon) is composed of a reddish-purple, close-grained, felsitic rock, which rises in a steep cliff towards the south and east, but slopes more gradually towards the north and west. On the north side, the rock shows a marked tendency to split into thin plates, which give a sharp, metallic sound, when struck with the hammer. So very marked is this tendency to split into thin plates, that it is extremely difficult to obtain a specimen of any thickness. On the south side, the rock is much more compact, and breaks with a conchoidal fracture.

The rock composing the Black Hill is somewhat different from that already described. When the hill is traversed from north to south, the rock is seen to vary on its two sides. On the north side the hill terminates abruptly in a vertical face of rock of a dull, brownish-pink colour. The rock is traversed by well-marked joints, which, in places, produce a rudely columnar structure; on weathered surfaces there is a tendency to split into slabs. In the lower part of the rock some exquisite flow-structure can be seen. This I was able to trace for about 20 feet from the base, although at times it was obscured by the lichens which cover the rock. Usually the banding of the flow runs parallel with the horizontal joints in the rock; but in certain places it is much contorted. At one place it deviated sharply from the horizontal line, and was traced in an almost vertical direction for 20 or 30 feet, where it was lost on account of the steepness of the rock.

On the south side of the hill, the rock is of a dull, reddish-pink colour, and is much more decomposed than that on the north side. The felspars have, in many cases, been dissolved out, leaving their casts, which are sometimes partly filled with chalcedony. This character is, however, not very constant; for in certain places the rock is hard and compact, ringing under the hammer and breaking into thin slabs.

Petrographical Description.

The rocks from Middle Eildon are all of felsitic texture. On a fresh fracture a few cleavage-faces of a clear felspar may be seen; and by the aid of a lens a bluish-green mineral can be recognized all through the base of the rock. In some of the specimens

a banded structure is seen; this is accentuated by the segregation of iron oxide along the bands.

Under the microscope, the banded rock shows a trachytic structure; it is of a non-porphyritic character, only a few large sanidines being scattered through it. These show irregular outlines; are often corroded; and when examined between crossed nicols, break up into a granular aggregate. This arrangement of the larger felspar crystals is characteristic of this lava-flow. The sanidine crystals also show the irregular series of cracks at right angles to their direction of elongation, which is so characteristic of them in all lavas. The base of the rock is made up of felspar microlites, a bluish-green mineral, and a colourless mineral of low refractive index and double refraction.

The bluish-green mineral occurs in small pieces, often grouped together, and moulding the felspars in the same way as augite does in many of the basic rocks. Between crossed nicols these patches extinguish together, showing that they are parts of the same crystal. Many of the pieces show cleavage-lines parallel to their sides, and one or two likewise show the hornblende cleavages. The extinction angle, measured from the longitudinal cleavage-lines, was 5°. When rotated over the polarizer this mineral showed intense pleochroism. Owing to the small size of the pieces I was unable to obtain a satisfactory figure from which to determine the axes of elasticity; but referring the colours to the crystallographic axes, the scheme of pleochroism is as follows:—

Parallel to c	...	...	deep blue.
„ „ b	...	...	deep blue-green.
„ „ a	...	...	pale yellow-green.

All the characters above cited point to the conclusion that the mineral is the soda-amphibole—riebeckite. But, as Rosenbusch has shown, it is the axis a, and not c, which makes an angle of 5° with the vertical axis; the scheme of pleochroism thus becomes $a > b > c$. This mineral forms fine ophitic patches with the felspar, but in certain parts of the rock it is replaced by a pseudomorph of iron oxide, which preserves intact the outlines of the original patch.

In one or two places glomero-porphyritic patches of sanidine and colourless diopside were observed; a few altered porphyritic augites and a little altered ægirine were also present in the section.

Scattered through the base of the rock are some brownish altered patches, which, when examined with a quarter-inch objective, are seen to consist of felspar microlites, and another mineral of lower refractive index, which remains almost isotropic when rotated between crossed nicols. This mineral occurs in irregular patches which extinguish in definite areas, and mould the felspar microlites. In certain places four-sided and irregular six-sided plates were observed, the former extinguishing parallel to their edges, and the latter giving a uniaxial, partial interference-figure in convergent polarized light. Nearly all the plates of this mineral were slightly

altered, and some were in an advanced stage of zeolitization. In extremely thin sections the difference in the polarization-colours of this mineral and the felspar microlites was much more plainly seen. From these optical characters I have concluded that the mineral is nepheline. As a confirmatory test, another thin section was prepared, and exposed to the vapour of strong hydrochloric acid for half an hour. It was then washed with warm water, covered with a saturated solution of malachite-green, and set aside for fifteen minutes. (This material was chosen in preference to fuchsine, because, according to Behrens, it does not give accidental stains—a great drawback to the use of the latter substance.) The section was now washed once again with warm water, a camel's-hair brush being used to remove any superfluous staining material. After the section was mounted in canada balsam and covered, it was found on examination under the microscope that the mineral moulding the felspars had been etched and stained deeply, while the latter remained untouched.

By way of comparison, a thin section of the phonolite-trachyte from Traprain Law was prepared and treated in a similar way. The staining showed the relations between the nepheline and felspar in this rock to be different to those existing in that from Eildon; for, while in the latter, nepheline moulded the felspars, in the former it seemed to be present in more or less idiomorphic plates.

In general structure the two rocks are very similar, except that in the Traprain Law rock the ferro-magnesian mineral is ægirine, which is present in a granular condition, while in that from Eildon it is riebeckite, which is often ophitic.

On the south side of the hill, the rock assumes a much more felsitic character; its fracture is conchoidal; and porphyritic felspars are very rare. A blue mineral can be seen scattered in patches through the rock, which by the aid of a lens can be recognized as riebeckite.

Under the microscope, the rock is seen to consist of felspar microlites, and patches of riebeckite or pseudomorphs after it. Ferruginous alteration-products are scattered thickly through it, giving a pinkish colour to the section, and rendering the rock so dense that it requires great care to obtain a section thin enough to be transparent. A few granular aggregates of felspar (sanidine) are present in the slide, some of which show zoning, and a rude attempt at perthite structure when examined between crossed nicols. The riebeckite exhibits the same characters as in the previous rock, except that its pleochroism is more intense. Between crossed nicols, the base of this rock is seen to be under strain; it also breaks up into patches which polarize in two distinct tints. One set of patches gives the extremely low colours of nepheline, and when examined in ordinary light shows greater alteration than the other. Small rectangular sections, much altered, were also observed giving the same polarization colours. From the very close resemblance of these patches to those in the rock previously described, there seems to be little doubt that they are composed of nepheline.

Easter Eildon.

The rocks composing this hill are typical trachytes. In hand-specimen they show, on a fresh fracture, the cleavage-faces of a sanidine felspar, in some cases slightly kaolinized; they have the general rough appearance and feel which characterize trachytes.

Under the microscope the rock is seen to consist of porphyritic sanidines set in a base of felspar microlites, among which is scattered a good deal of limonite evidently pseudomorphous after riebeckite, as it retains the exact outlines of the original ophitic patch. The porphyritic sanidines are resolved into granular aggregates between crossed nicols. In some of these there has evidently been a growth of the crystal after the consolidation of the rock, as there is evidence in some cases of an attempt to assume a crystal form. A notable feature of the felspars of this rock is the number of sections which give a biaxial figure in convergent polarized light. Some of the larger crystals have been dissolved away and their places filled up by secondary quartz. Sections of the rocks from other parts of the hill did not show any very different characters; a special description is therefore unnecessary.

Between these rocks and that from Ailsa Craig described by Mr. Teall, there is a great similarity. Their ground-mass is almost identical with that of the Ailsa Craig rock; the riebeckite is in ophitic patches, and shows the alteration into pseudomorphs of iron oxide in both cases; and, except for a larger quantity of quartz in the latter rock, the resemblance is very striking. If similarity of structure and composition be of any value in determining the age of a rock, perhaps the fact of the rocks just described being of Upper Old Red Sandstone age may help to suggest the age of the Ailsa Craig rock.

Black Hill.

Banded Rock.—Macroscopically, this rock shows two sets of bands. One half consists of alternating bands of brown and greyish-pink $\frac{1}{32}$ of an inch broad, the other of bands $\frac{1}{8}$ of an inch in thickness. Porphyritic sanidines, somewhat altered, occur here and there, lying across and breaking the bands.

Microscopically, the rock consists of a finely felted mass of sanidine microlites with their long axes lying parallel to the banding. Porphyritic crystals are rare, and when present occur in granular aggregates. They are all more or less altered, and show the irregular cracks across the prism so characteristic of sanidine in the more recent trachytes. No ferro-magnesian mineral is present in this rock; but there is evidence of its presence at an earlier period of its history, in the ferruginous alteration-products which have been shown to be formed from riebeckite in the other rocks. These alteration-products have segregated along the flow-lines, thus producing the beautiful banded appearance.

The other rocks (unbanded) are very similar in microscopic structure to that described above; there is therefore no necessity for a detailed description.

Junction between Sandstone and Igneous Rock, on the South Side of the Hill.—Macroscopically, the rock resembles the claystone porphyrites in appearance. It shows signs of minute spherulitic structure near the junction with the sandstone. The line of junction is not straight and sharp, but the igneous rock has sent small offshoots into the sandstone. It is thus highly probable that the sandstone was in a loose unconsolidated state when the lava was poured over it.

Microscopic examination of a section shows the trachyte to be a good deal altered. It has evidently been originally a glassy rock containing a few porphyritic crystals of sanidine which are now replaced by chalcedony. The glass, which is now largely devitrified, is crowded with altered spherulites. The devitrified base has the appearance of the highly siliceous ground-mass of the felsophyres of the acid rocks. It is thus highly probable that a good deal of quartz has been fused and incorporated in the lava along the line of contact.

The sandstone also shows signs of fusion along the line of contact with the trachyte. The sand-grains are cemented together by a finely crystalline aggregate of quartz. Along the junction-line, the grains show much corroded outlines, and many of them show a ring of fused material having very indefinite boundaries. Where the trachyte has sent veins into the sandstone, lines of fusion are seen which much resemble the fluxion-structure of a rhyolite. Round these veins the quartz has been fused; it is now in the form of chalcedony. In the sandstone itself, mica is seen to be developing; and there is a good deal of felspar, mostly unaltered plagioclase showing lamellar twinning.

Another specimen of sandstone, taken one foot below the junction-line, had lost all traces of bedding, and broke with an irregular fracture. Scales of a silvery mica were seen lying in all directions and at all angles to the bedding-planes, thus proving that they have been developed subsequent to the deposition of the sandstone.

Under the microscope, the mica proved to be muscovite. Fresh plagioclase has also been developed; and the cementing material between the sand-grains has been made to assume a finely granular form.

The presence of fresh plagioclase in a sandstone is not an every-day occurrence, and it is necessary to find an explanation to account for it. Sandstone, being a porous rock, is not likely to contain the alkalies necessary for the formation of plagioclase felspar, because of their solubility in water. They must, therefore, have been derived from another source, that being the overlying igneous rock. It was noticed that no ferro-magnesian mineral was observed in the overlying rock; but there was a good deal of iron oxide scattered through it, which was shown to be derived from the alteration of riebeckite in the Eildon rock. This mineral, being a soda-amphibole, might, by its decomposition, supply the alkali necessary for building up a felspar such as albite; and I am inclined to regard this as the true explanation of the presence of fresh plagioclase in the sandstone.

I have only to add that this work has been done in the Geological Research Laboratory of the Royal College of Science; and to express my thanks to Professor Judd for the assistance and many valuable suggestions that he has given me.

REVIEWS.

I.—Catalogue of the Jurassic Bryozoa in the British Museum (Natural History). By J. W. Gregory, D.Sc., F.G.S., F.Z.S. (1 vol., 8vo; pp. 240, 11 Plates.) London: 1896. Printed by order of the Trustees. Dulau & Co., 37, Soho Square, W. Price 10s.

THIS volume is the first of a series, which, when completed, will form a Catalogue of the fossil Bryozoa in the British Museum. Dr. Gregory explains that he has begun with the description of the Jurassic Bryozoa, because "it is among the Jurassic deposits that we must seek the ancestors of existing types," and because the primary lines of divergence are here well marked, and not obscured by secondary variations of later periods. Further, it was necessary to work out the Jurassic fauna before attempting the Cretaceous, which, of all British Bryozoan faunas, is most in need of further investigation. Of the seventy-nine species here described, sixty-nine are included in the Cyclostomata, eight in the Trepostomata, and two in the Cheilostomata. The Cryptostomata, which occur so abundantly in Palæozoic times, and which are usually assumed "to take the place of" the Cheilostomata, have not been found in the Jurassic strata. The Trepostomata, which likewise prevailed in the Palæozoic strata, form a dwindling remnant in the Jurassic. The Cheilostomata, which preponderate in later times, have not yet risen into importance.

The classification of the orders is based on zoœcial[1] characters. The Trepostomata are characterized by the *change* in the nature of the distal as compared with the proximal parts of the zoœcial tubes, by the presence of mesopores, diaphragms, acanthopores, etc. The order Cyclostomata, which includes 87 per cent. of the species here catalogued, is separated from the others rather by its negative characters. Dr. Gregory divides this order into four suborders: 1, Articulata (including Crisiidæ); 2, Tubulata; 3, Dactylethrata; 4, Cancellata (including Discoporellidæ). The first and fourth do not occur in the Jurassic deposits. Accordingly, the Jurassic Cyclostomata fall into two groups—the Tubulata (including 65 species), in which the zoœcia are monomorphic; and the Dactylethrata (including 4 species), in which aborted closed zoœcia or "dactylethræ" are present in addition to the normal open ones.

It has always been a difficult matter to satisfactorily classify the forms (recent as well as fossil) included in the Tubulata. The zoœcial characters are of no use in the splitting up of this suborder

[1] *Zoœcium*, the individual tube or cell containing in life the polypide; *zoarium*, the colony of tubes or cells.

into families and genera, or in founding wholly artificial groups. Consequently the systematist is compelled to trust to zoarial characters. When he finds that a change in environment appears to bring about a change in zoarial habit in a species, and that types of zoarial growth characteristic of different "genera" may occur in the same specimen, and further, that transitional forms link together the types of zoarial growth assumed to be of generic or family importance, then it is that he feels the need of caution in applying such terms as family and genus to groups of forms classified according to zoarial characters. As a philosophical naturalist, Dr. Gregory is inclined to group at least the first section of the Tubulata under one genus. As a working palæontologist, he retains the well-known generic names, but with the understanding that such names are merely labels attached to certain groups, the members of which resemble each other more than the members of neighbouring groups. In place of the word "genus" Dr. Gregory suggests "circulus," a term applied to the groups of listeners which congregated round orators in the Forum.

Minor characters of the zoœcial tubes are made use of to distinguish species. Dr. Gregory has framed a very useful "variational formula," whereby "the range of variation within the limits of a certain specific group may be conveniently shown." The elements taken into account are the peristome or distal end of the zoœcia, the shape, the length, and the amount of aggregation of the zoœcia, four degrees (0, 1, 2, 3) of variation being calculated. By means of this formula, it is easy to accurately tabulate and compare the slight variations that may occur, let us suppose by way of example, in specimens of the same species occurring in consecutive strata or epochs.

We regret to have to point out that a short corrigenda list is necessary. The text is liberally illustrated by numerous woodcuts, and by eleven plates, the artistic finish of which is excellent.

Laborious research, scientific method, and artistic skill have contributed to form a volume which maintains the honourable traditions of the British Museum; and it is to be hoped that Dr. Gregory will complete the work he has so well begun.

II.—Bollettino della Società Sismologica, Vol. I, 1895. pp. 168 + 230.

De Rossi's valuable *Bullettino del Vulcanismo Italiano* was begun in 1874, and ceased to exist in 1889 or 1890 after a few parts of the seventeenth volume had been published. Its place is now worthily supplied by the *Bollettino* of the Italian Seismological Society, founded under the direction of Prof. Tacchini in the spring of last year. Though nominally a society, it does not appear that any meetings have been held; indeed, the members are so widely scattered, so few are collected in any one place, even in Rome, that regular meetings would be hardly possible, and the exertions of the members are wisely confined to the publication of their journal.

The first part of the volume contains 27 short papers. The second

and larger part is contributed by the Central Meteorological and Geodynamic Office at Rome, and consists of notices of the earthquakes observed in Italy during 1895. It is not, however, of merely local interest, for many of the records are those of distant shocks, and supply valuable time-determinations for measuring the velocity with which the pulsations travel.

That the invention of new instruments continues to occupy Italian seismologists, is shown by the insertion of no fewer than eight papers. The Guzzanti microseismograph is described by its inventor, and the Cecchi microseismograph, which has been in use for some time, by G. Giovannozzi. Prof. G. Mugna describes an electrically-recording seismoscope; Dr. A. Cancani, a new type of seismic photochronograph; and Prof. G. Grablovitz shows how the horizontal pendulum may be adapted for recording the time of occurrence of a shock. Accounts are also contributed by their respective inventors of Vicentini's microseismograph, Agamennone's seismometrograph, and Grablovitz' geodynamic level, instruments which have already added to our knowledge of earthquake-pulsations.

Several interesting earthquake-studies are supplied by the staff of the Meteorological and Geodynamic Office. The well-known Director, Prof. P. Tacchini, describes the Roman earthquake of Nov. 1, 1895; while his assistant, Dr. M. Baratta, deals with the Lecco earthquake of March 5, 1894, the Viggianello earthquake of May 28, 1894, the Laibach earthquake of April 14, 1895 (so far as it was felt in Italy), the Florentine earthquake of May 18, 1895, the Adriatic earthquake of Aug. 9, 1895, and with the Florentine seismic district generally. Dr. G. Agamennone, the Director of the Constantinople Geodynamic Office, discusses the earthquake of Paramythia (Epirus) of May 13–14, 1895; and Prof. F. Omori determines the surface-velocity of several recent Japanese earthquakes.

The Italian volcanoes receive their due share of attention. Prof. G. Mercalli communicates Vesuvian notes from January, 1892, to June, 1895; and Prof. A. Riccò, notes on the state of Etna from the eruption in 1892 to the end of 1894. A summary of the principal eruptive phenomena in Sicily and the adjacent islands is added by S. Arcidiacono, and some observations made on Vesuvius on June 21, 1895, by Dr. M. Baratta. C. Davison.

III.—Miocene and Pliocene Mammals in Russia. Nouveaux Mammifères tertiaires trouvés en Russie. By Marie Pavlow. Bull. Soc. Imp. Nat. Moscou, 1896, No. 2, pp. 1–12 (reprint), with one plate.

MADAME PAVLOW'S latest contribution to our knowledge of the extinct Mammalia of Russia is an interesting description of some fragmentary remains referable to an earlier date than the Pleistocene. *Anchitherium aurelianense* is recorded for the first time from Russia, on the evidence of the distal end of a metacarpal III from the neighbourhood of Nikolaew. *Rhinoceros Schleiermacheri* is represented by two molars, *Capreolus cusanus* by two imperfect antlers and one lower molar, and a *Cervus* (much like *C. Perrieri*)

by a metacarpal, all from the sandy beds of Balta, in the Government of Podolsk. A lower jaw from Balta, believed to belong to *Mastodon turicensis*, is also described from a photograph, the original specimen having apparently been lost. According to Madame Pavlow's list of the mammals, the "sables de Balta" are characterized by a curious fauna. In addition to the species mentioned above, there are already identified *Dinotherium giganteum*, *Hipparion gracilis*, *Rhinoceros megarhinus*, *Mastodon ohioticus*, *Mastodon arvernensis*, and *Mastodon Borsoni*.

REPORTS AND PROCEEDINGS.

Geological Society of London.

June 24, 1896.—Dr. Henry Hicks, F.R.S., President, in the Chair.

Death of Sir Joseph Prestwich, D.C.L., F.R.S., F.C.S., F.G.S.

The President said: It is with deep regret that I have to announce to you the death of our dear and much-beloved friend, Sir Joseph Prestwich. He was elected into the Society in the year 1833, and we had come to look upon him as the father of our Society. He served it as Treasurer and President and was one of its Wollaston Medallists, and we feel that by his death our Society loses one of its truest friends. He always gave us of his best, and delighted to communicate his knowledge to his fellow-workers. He was in every respect a typical representative of our Society and its objects, for he passionately loved the science, fearlessly maintained what he believed to be the truth, and had that open mind and craving for knowledge which have ever characterized the best and noblest of its members. This is not the time to refer specially to his labours; but we may feel assured that such sterling work as he accomplished will ever hold an honoured place in the annals of British Geology. The Council, at their sitting this afternoon, passed the following resolutions, which I feel no doubt all the Fellows present will cordially endorse:—

(1) That the President, Council, and Fellows of the Geological Society of London desire to convey to Lady Prestwich the assurance of their heartfelt sympathy with her in the sad and irreparable loss that she has sustained, and at the same time to place on record their high appreciation of the lifelong geological work achieved by Sir Joseph Prestwich, who for sixty-three years was a member of their body alike respected and beloved.

(2) That this Resolution be placed upon the Minutes, and a copy of it be communicated to Lady Prestwich.

The above Resolutions were then passed unanimously.

Sir William Dawson, C.M.G., F.R.S., exhibited specimens and lantern-slides illustrating the general form, arrangement of laminæ, and distribution of the canals and tubuli in characteristic specimens of *Eozoon canadense*. He pointed out that an examination of these specimens and photographs might prevent mistakes likely to arise from the study of imperfect specimens or from supposing that laminated rocks resembled *Eozoon*, and also that they exhibited additional peculiarities observed since the original publication of the description of *Eozoon* in the Quarterly Journal of the Society in 1865. He did not wish to enter upon any argument as to the nature of *Eozoon*, but merely to show the appearance of the principal structures on which the conclusion that it was of animal origin had been based. He also pointed out that these structures might be misunderstood when studied in imperfectly-preserved specimens, and that the wonder was not that so many specimens were imperfect, but that any structure had been preserved. He also shortly noticed the growing probabilities in favour of the existence of a rich marine fauna in pre-Cambrian times, and some of the discoveries in this direction already made or in progress.

The following communications were read :—

1. "Notes on the Glacial Geology of Arctic Europe and its Islands. Part II: Arctic Norway, Russian Lapland, Novaya Zemlya, and Spitzbergen." By Colonél H. W. Feilden, F.G.S. With an Appendix by Professor T. G. Bonney, D.Sc., LL.D., F.R.S., V.P.G.S.

The author gives an account of observations made in Arctic Norway which tends to prove that the shell-bearing terraces are true marine deposits indicating uplift since their formation, and that they were not formed by ice-dams. He then describes terraces recently formed in Kolguev Island, which illustrate the combined influence of pack-ice, sea-waves, and snow on the formation of terraces in a rising area. The glacial geology of the Kola Peninsula is next considered, and the distribution of the boulders noticed. There is no doubt that these boulders have been derived from local rocks, and that no ice-sheet from the North ever passed through Barents Sea or impinged on the northern coast of Europe.

The author saw no evidence of the former extension of an ice-sheet over the now frost-riven rocks of Novaya Zemlya. He found widespread deposits of boulder-clay with marine shells in this region, which he attributes to the action of floating ice. In the Kostin Schar many of the islands are connected by ridges covered with rounded stones pushed up by floe-ice, with solid rock beneath glaciated by the floe-ice. Several minor phenomena connected with the glacial geology of Novaya Zemlya are also described. The raised beaches of Franz Josef Land are noticed, and immense deposits occurring in Spitzbergen, which were originally formed under water in front of glaciers, alluded to. These, as well as other submarine deposits of glacio-marine origin seen elsewhere by the author, show no signs of stratification.

Prof. Bonney described specimens brought by Col. Feilden from Norway, the Kola Peninsula, and Novaya Zemlya. From an examination of the rocks obtained *in situ* in the last-mentioned region, Prof. Bonney confirms Col. Feilden's suggestion that the Kolguev erratics may have come from Novaya Zemlya.

2. "Extrusive and Intrusive Igneous Rocks as Products of Magmatic Differentiation." By Prof. J. P. Iddings, For. Corr. G.S.

The author, after pointing out the propositions concerning differentiation of magmas upon which he is in agreement with Prof. Brögger, discusses the points of difference, and describes the relation of the igneous rocks at Electric Peak to all of those which took part in the great series of eruptions which occupied almost the whole Tertiary period, and spread themselves over a vast territory in Montana, Wyoming, and Idaho. In Tertiary times the eruptions were at first largely explosive, and the accumulation of tuff-breccia formed a chain of lofty volcanoes, comparable with the Andes in size as well as in the nature of their material (andesite and andesitic basalt). After considerable erosion of these volcanoes, gigantic fissure eruptions flooded the region west of the denuded volcanoes. The massive lava-streams which welled from these fissures consisted at first of rhyolite with an average silica-percentage of about 74, alternating occasionally with basalt; but the great bulk of the basalt was poured out immediately after the rhyolite from fissures still farther to the west and south-west. In the case of these extrusive rocks, whose volumes are of such magnitude, the evidence drawn from the succession of their eruptions and from their composition is of a higher order than that derived from the smaller and more localized eruptions; and it is upon evidence of this order that the author ventured to enunciate the principle that in a region of eruptive activity the succession of eruptions in general commences with magmas representing a mean composition and ends with those of extreme composition.

CORRESPONDENCE.

MR. DUGALD BELL AND THE PARALLEL ROADS OF GLENROY.

Sir,—Did time allow, it would be easy to show that Mr. Dugald Bell's criticism of my remarks on the Parallel Roads of Glenroy (page 319) is a typical instance of forensic advocacy. But I am leaving England for the Alps, so that Lochaber must rest in peace. Whether on my return it will be worth while spending time in travelling over well-worn paths, is a doubtful matter. Nothing can be settled about Glenroy till some fresh evidence turns up. Meanwhile Mr. Dugald Bell may rest assured that I am not frightened at being in a minority. I have lived and been a geologist long enough to have watched the apparition and the fading away of many Brocken-spectres, not in our science only.

T. G. Bonney.

July 3rd, 1896.

FOSSILS IN THE *OLENELLUS* SANDSTONE OF NUNEATON.

SIR,—The publication of the May number of the Quarterly Journal of the Geological Society has reminded me of a correction which I ought to have made before, and for which I am alone responsible. On page vi, in the first paragraph, in speaking of fossils collected by Professor Lapworth from the *Olenellus* Sandstone of Nuneaton, I give a list of determinations which were merely approximate, without any warning to that effect. I have since learned that these determinations were not intended to be final, and therefore I ought to have inserted the letters *cf.* before the six specific titles given in that paragraph. W. W. WATTS.

CORNDON, WORCESTER ROAD, SUTTON, SURREY.
June 10th, 1896.

MISCELLANEOUS.

RECENT ADDITIONS TO THE GEOLOGICAL DEPARTMENT OF THE BRITISH MUSEUM (NATURAL HISTORY), CROMWELL ROAD.

1. There has just been added to this gallery a very fine collection of flint implements, also numerous flint flakes, showing various stages and processes in their manufacture, and found associated with remains of *Rhinoceros antiquitatis* at Crayford, in Kent. Presented by F. C. J. Spurrell, Esq., F.G.S.

2. A collection of fossils from Devon and Cornwall, part of the museum of the late William Pengelly, Esq., F.R.S., comprising mammalian remains from Happaway Cave and Devonian Corals, Brachiopods, Trilobites, Cephalopods, etc. Presented by Mrs. Pengelly, of Lamorna, Torquay.

3. Remains of some remarkable extinct birds from the older Tertiary deposits of Santa Cruz, Patagonia. Many of these are of gigantic size: the lower jaw of one of the largest (*Phororhacos longissimus*) measured about twenty inches in length; the whole skull must have been fully two feet in length. The complete skull and mandible of a somewhat smaller form (*Phororhacos inflatus*) show the remarkable characters of the beak, which is hooked like that of a bird of prey, but at the same time is very deep and compressed. Acquired from Prof. Ameghino, of La Plata.

4. Some extremely well-preserved parts of skeletons of Plesiosaurs from the Oxford Clay of Peterborough have been mounted in one of the wall-cases. Part of the Leeds Collection.

5. Some remarkable reptiles, *Cynognathus* and *Gomphognathus*, from the Trias of South Africa, in which the teeth and skull had a superficial resemblance to those of carnivorous mammals. Presented by Professor H. G. Seeley, F.R.S., F.G.S.

6. A very rich collection of mammalian and reptilian remains from the Miocene Tertiary deposits of the "Bad-lands" of Dakota, North America, comprising many genera, such as *Titanotherium*, *Mesohippus*, *Oreodon*, *Poëbrotherium*, *Hoplophoneus*, etc. Acquired from Prof. W. B. Scott, F.G.S., of Princeton, New Jersey, U.S.A.